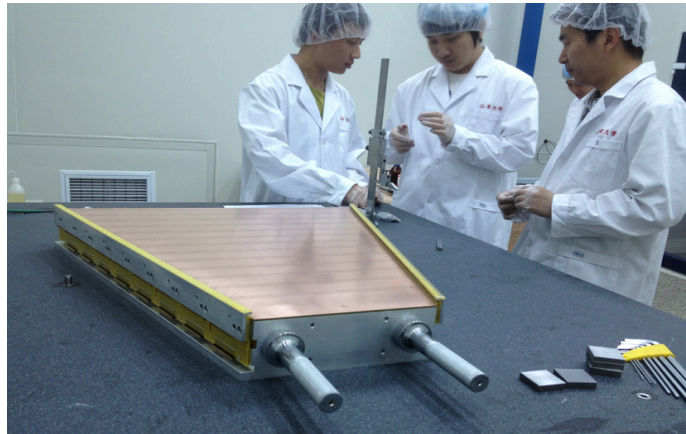


MWPC production plan and resources

Qinghua Xu(Shandong University)

MWPC review, Jinan, Dec. 3, 2016



Thanks to my colleagues:

Changyu Li, Jian Deng, Peng Lu, Yansheng Sun, Chengguang Zhu,

Fuwang Shen, Shuai Wang, Xu Wang, Fangang Kong,

Chi Yang (USTC)

+ other iTPC colleagues

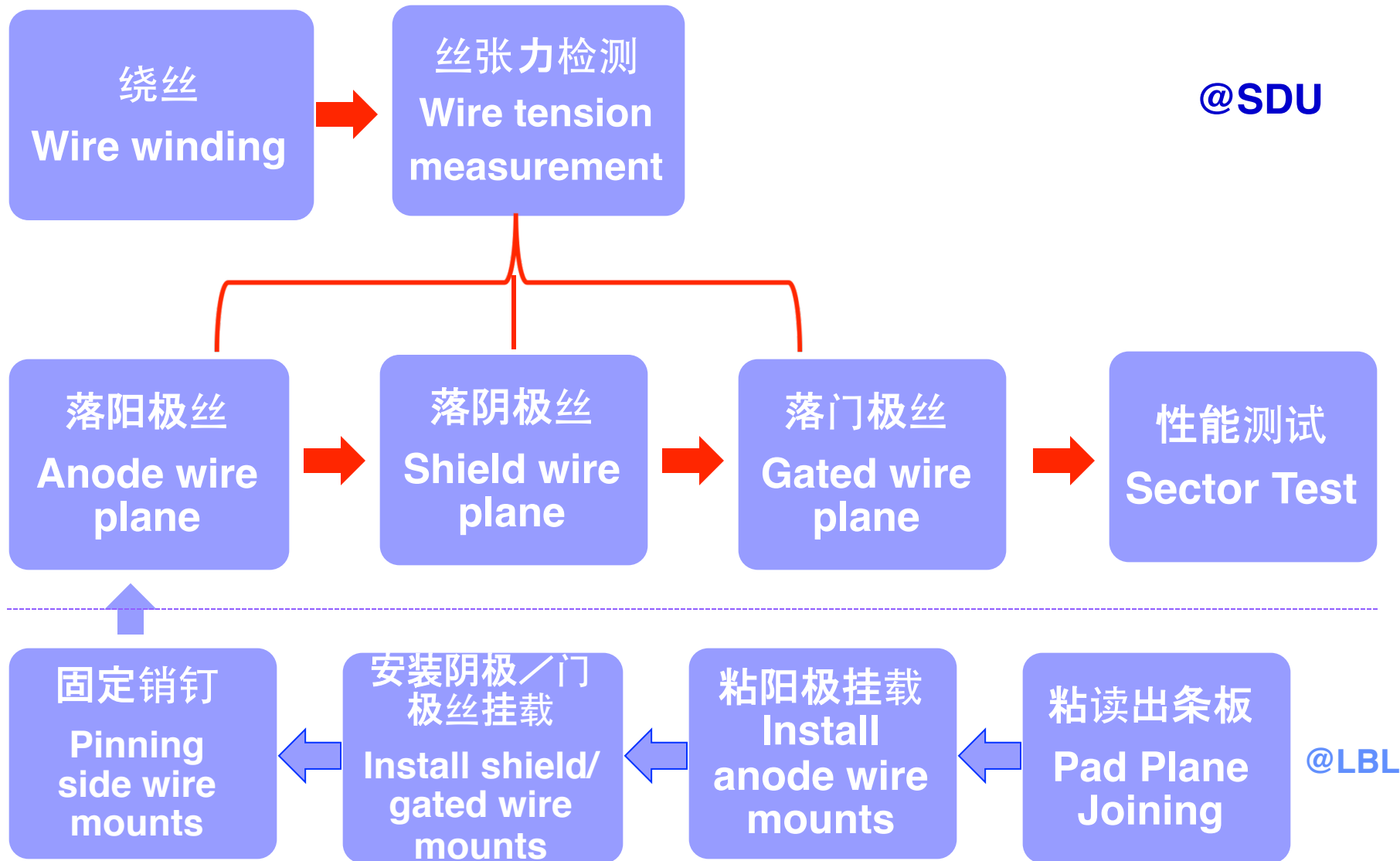
Outline:

- **Scope of effort with project**
- **Funding and man-power**
- **Facilities & laboratory**
- **Prototype work done**
- **Time scale of production plan**
- **Risks and mitigation**

Scope of effort with project

- **Prototype of iTPC sector**
- **27 wire plane production**
- **Assembly of 24+3 sector (after pcb bonding at LBL)**
- **Sector test (HV burn-in, uniformity, efficiency)**
- **Ship the 24+3 sectors to BNL**

MWPC production-main steps

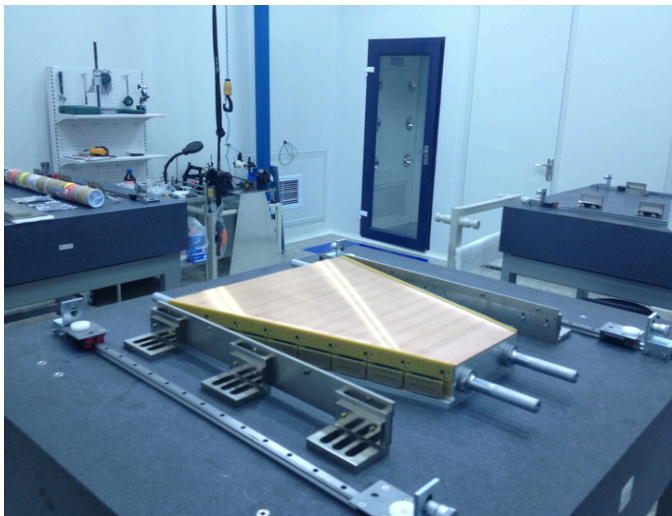


Funding & manpower in China for iTPC

- **6.5M RMB (~1M \$) support in total from China for MWPC :**
 - ✓ **2M RMB from MoST 973 key project for high energy nuclear physics (2014-2018)**
 - ✓ **3M RMB from NSFC key project for international cooperation (2016~2020), approved Sep. 2015.**
 - ✓ **1.5+ M RMB in-kind contribution from Shandong University.**
- **Manpower & institutions:**
 - ✓ **SDU: 2 faculties+ 1.5 engineers + 3 students+2(+1) technician**
- assembly, testing
 - ✓ **USTC: 1 professor+1 postdoc - testing**
 - ✓ **SINAP: 1 professor+1 postdoc - calibration**

MWPC- iTPC laboratory at SDU

- New building in 2000 for ATLAS Thin Gap Chamber (TGC). Produced 400 modules of high quality TGC for ATLAS during 1999-2004.
- The lab is $\sim 400\text{m}^2$, recently refurbished. New clean room built for iTPC project.
- Detector test system for detector testing.



Clean room with granite table



Clean room for wire winding, testing



Wire winding for MWPC at SDU

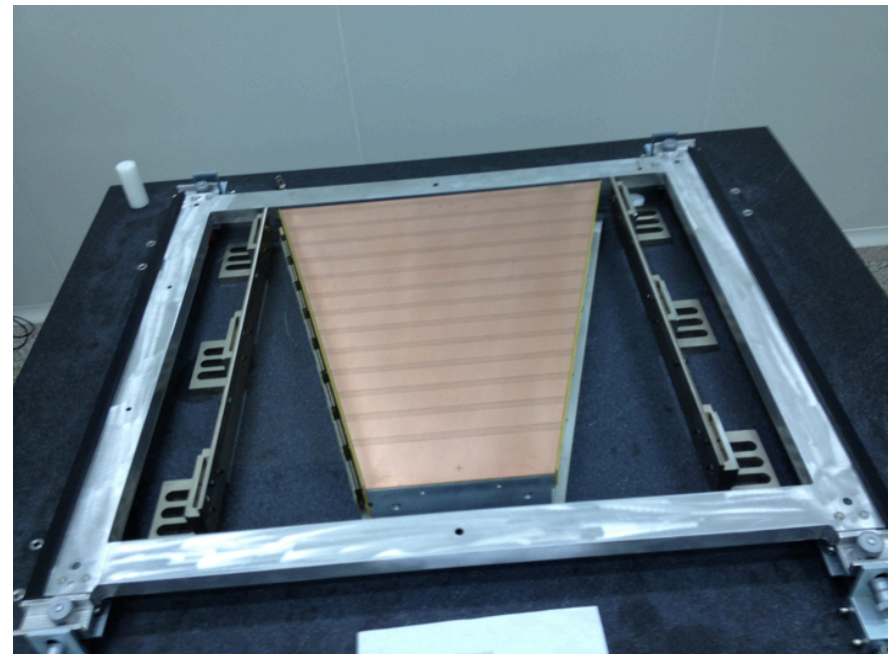
- **Three layers of wire for iTPC MWPC:**

-Wire pitch and tension controlled by winding machine, originally from Israel. New machine, upgraded from previous.

| Wire | Diam. (μm) | Pitch (mm) | Composition | Tension (N) |
|----------------------|-------------------------|------------|-----------------|-------------|
| Anodes | 20 | 4 | Au-plated W | 0.50 |
| Anodes— last wire | 125 | 4 | Au-plated Be-Cu | 0.50 |
| Ground plane | 75 | 1 | Au-plated Be-Cu | 1.20 |
| Gating grid | 75 | 1 | Au-plated Be-Cu | 1.20 |



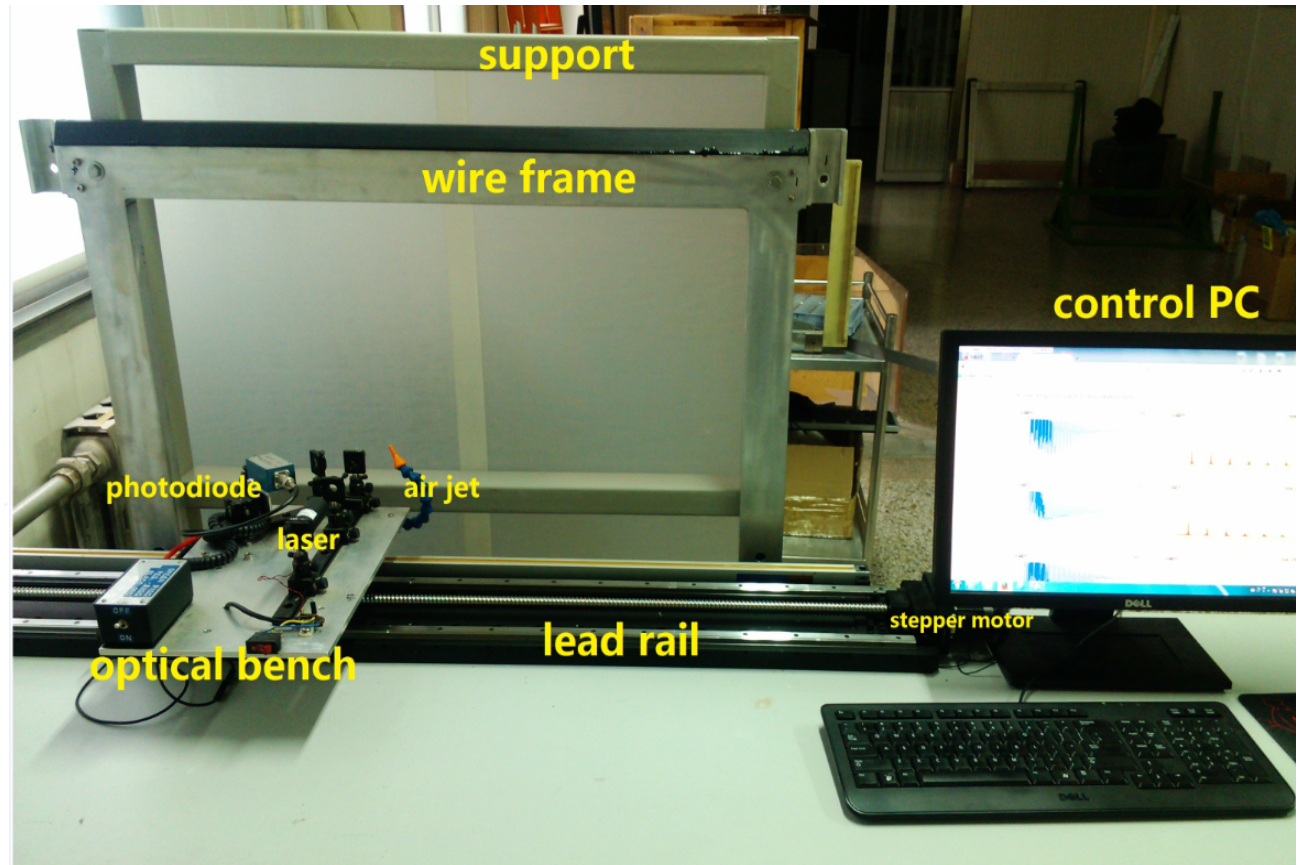
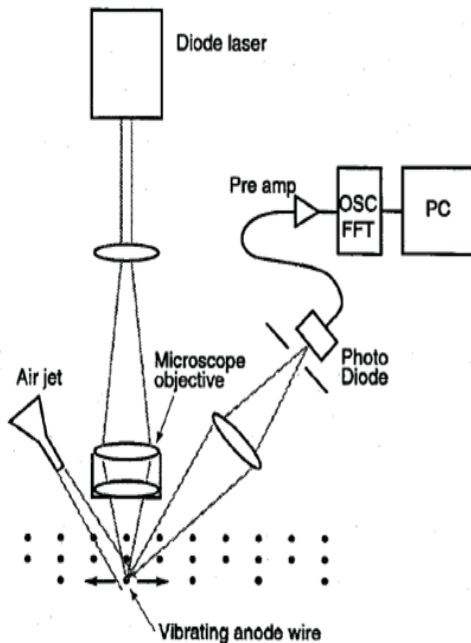
Wires first wound on frames, and then will be used for 3 layers of wire plane with wire combs, to keep height and pitch precisely ($\sim 10\mu\text{m}$).



Wire tension measurement system

- Determine wire tension by optically measuring the vibration frequency:

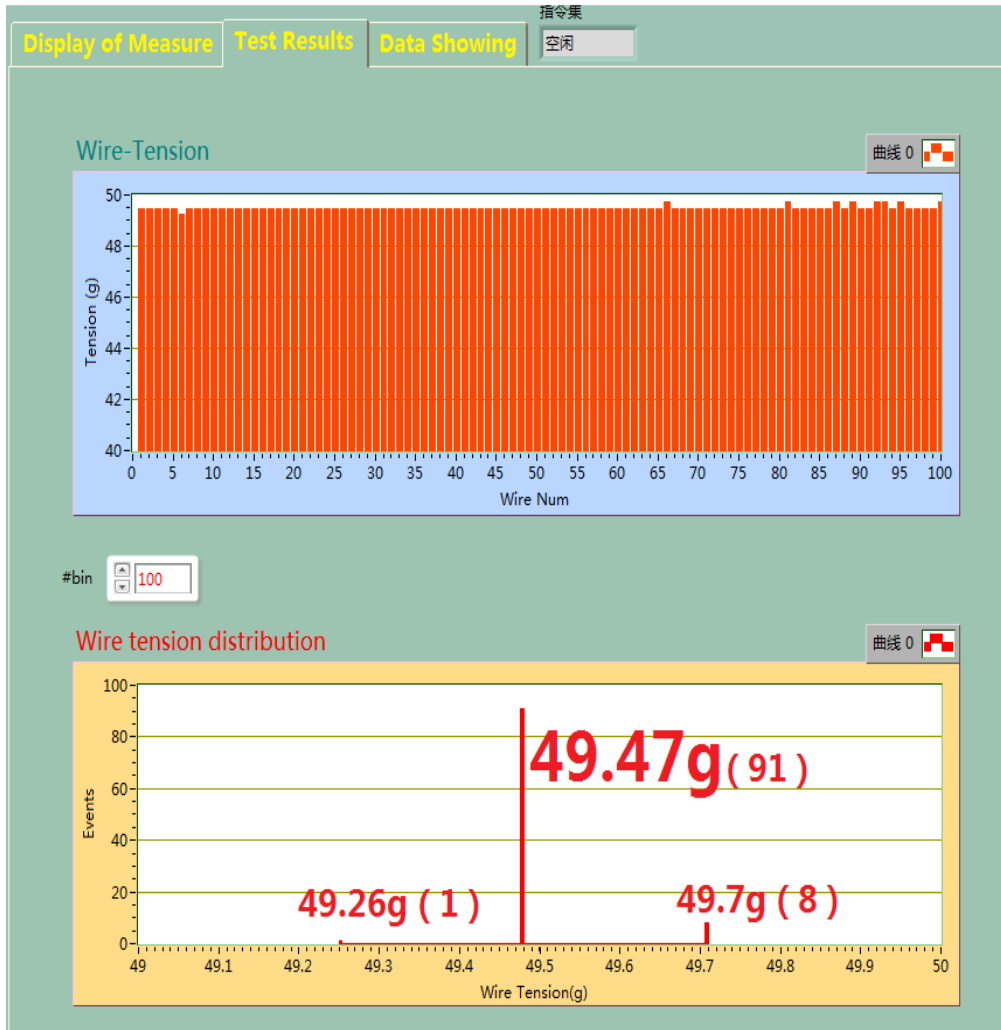
$$T = 4\mu f_0^2 L^2$$



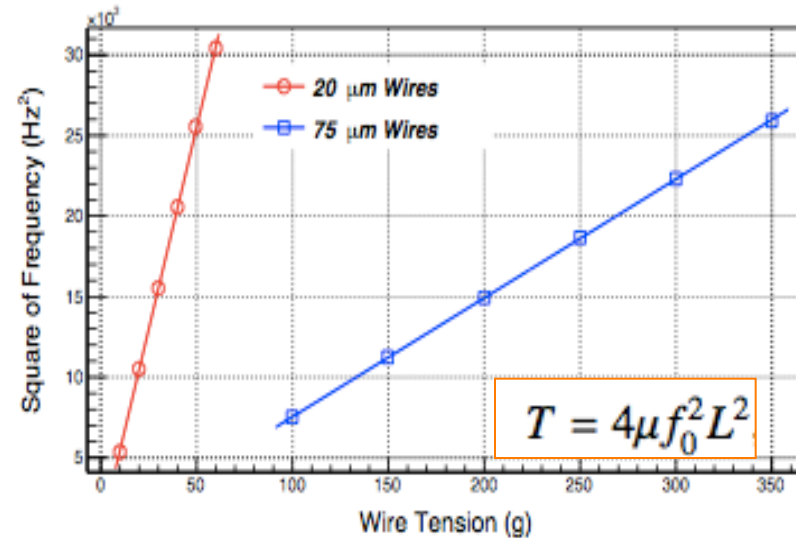
Laser scan each wire, synchronized with gas jet, and the base frequency will be extracted from voltage fluctuation transformed of laser absorption.

Wire tension measurement system

- Cross-check of the method with fixed tension wires:



Frequency square vs. Tension

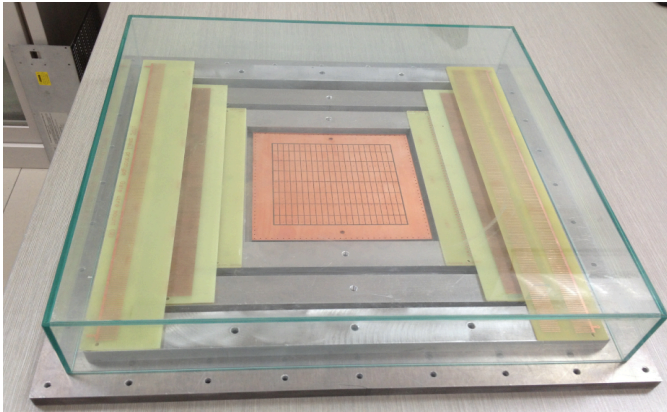


Measurement with fixed tension:
(<2%)

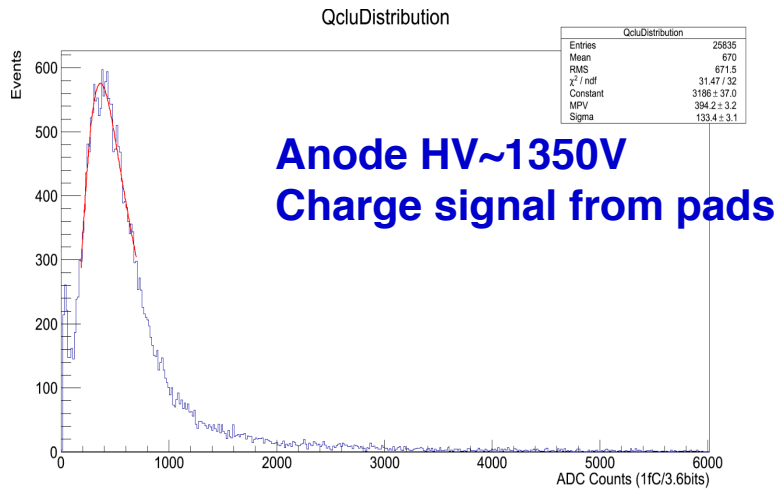
| Wires | 1 | 2 | 3 |
|-------|------|------|------|
| 50g | 49.5 | 50.8 | 50.6 |
| 60g | 60.9 | 60.6 | 60.4 |

Began with small MWPC prototype

- Small MWPC prototype made at SDU July 2014; Tested with cosmic ray system:



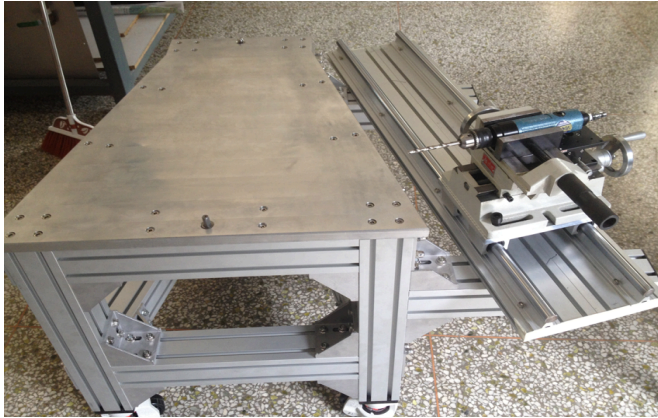
Small TPC prototype



Cosmic ray test system

Tools & fixture for full size prototyping

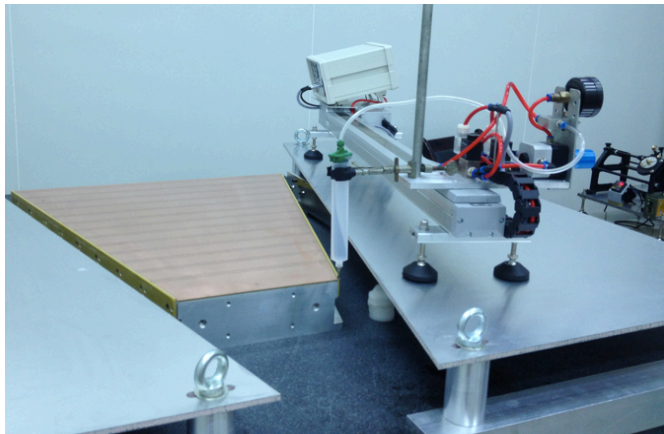
- Started the full size iTPC prototyping since September 2014. Several tools haven been made since then.



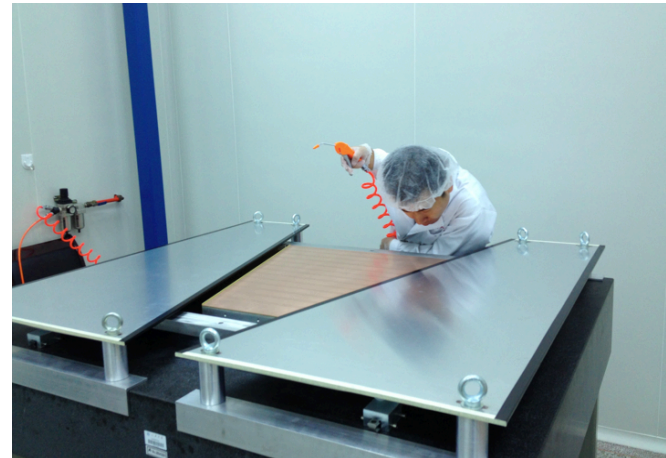
Drill/pin fixture



Gluing stand (anode WM)



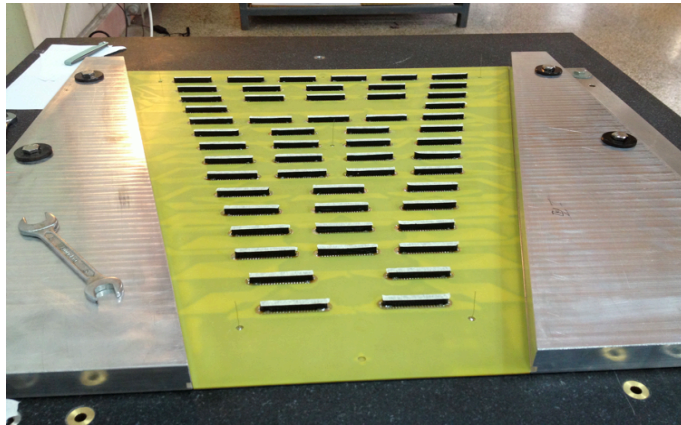
Gluing machine



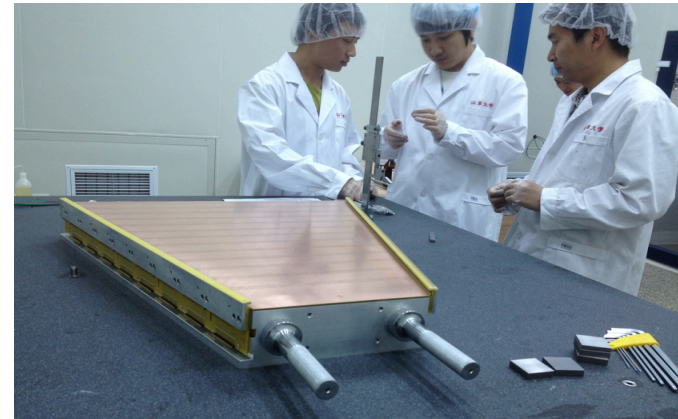
Protecting cover

Full size iTPC prototyping

- Gluing pad plane to strongback, install 3 side wire mounts:



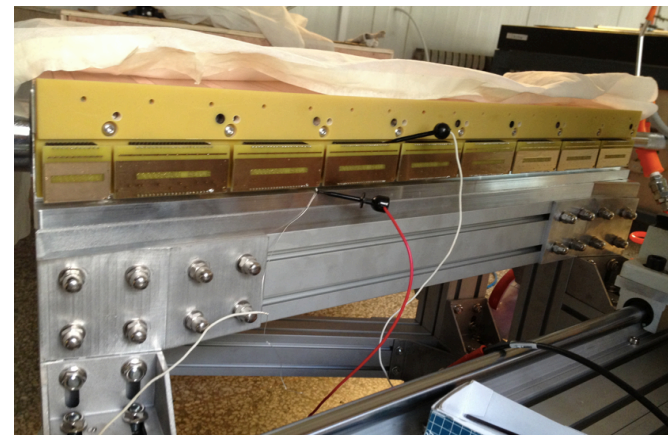
PCB bonding



Side wire mounts

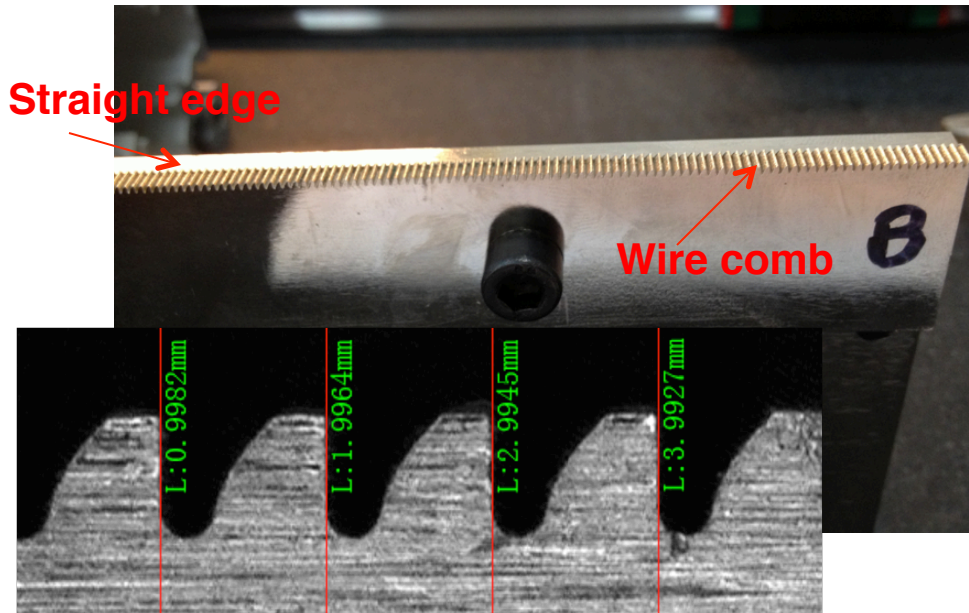


Pining the wire mounts



Leakage current, continuity, open test

Wire combs to keep wire pitch and height



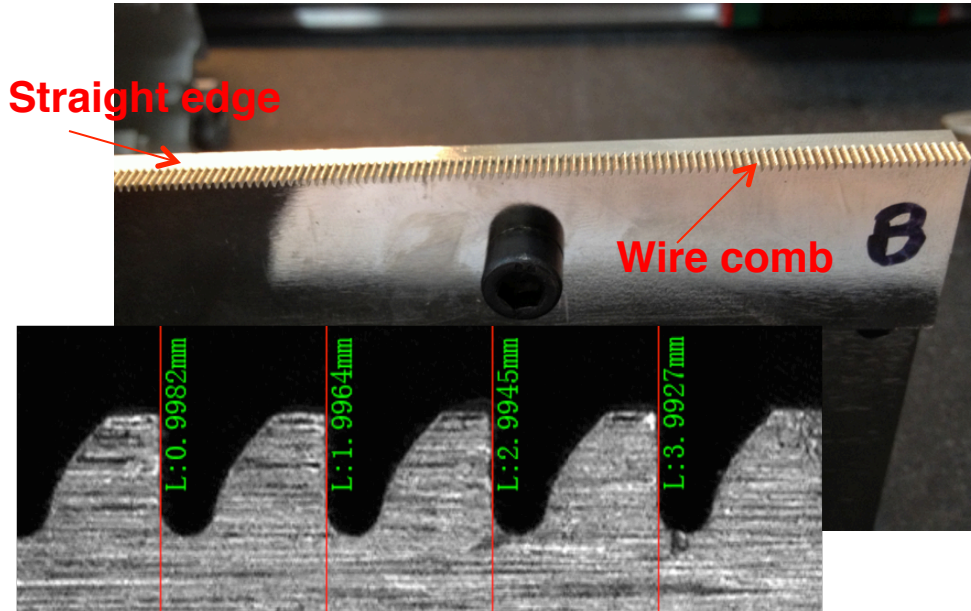
- Wire pitch and height is controlled by wire comb as originally used in STAR TPC.
- The flatness of straight edge should be $<10\mu\text{m}$.
- The combs produced by LBL will be used.

- Mounting wire combs using height standard (tolerance $<10\mu\text{m}$) and micrometer ($1\mu\text{m}$).
- Lowering down the frame to let the wire just touch the comb straightedge using micrometer head.

**Height standard ($\sigma < 10\mu\text{m}$)
(from granite table):**

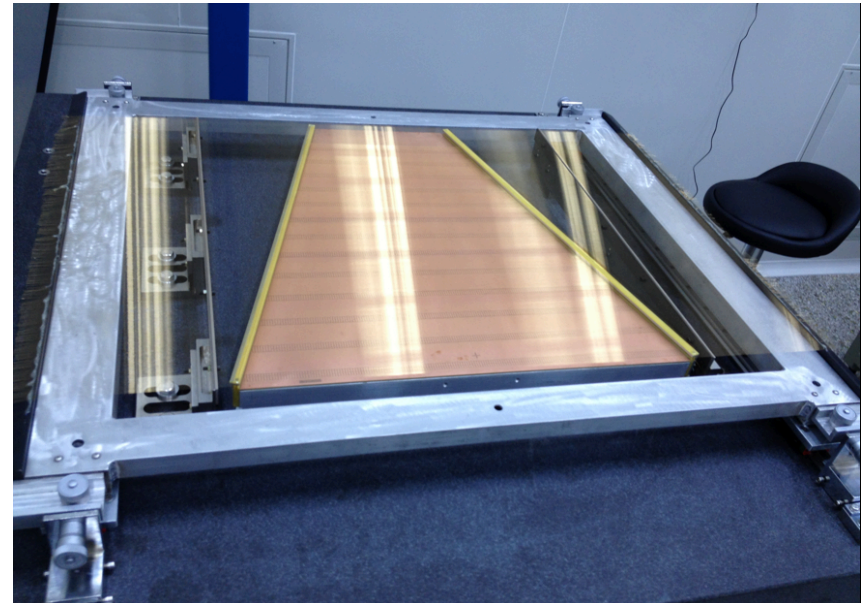
**Pad plane : 86.550mm
Anode Wire: 88.540mm
Shield Wire: 90.513mm
Gated wire: 96.513mm**

Wire combs to keep wire pitch and height

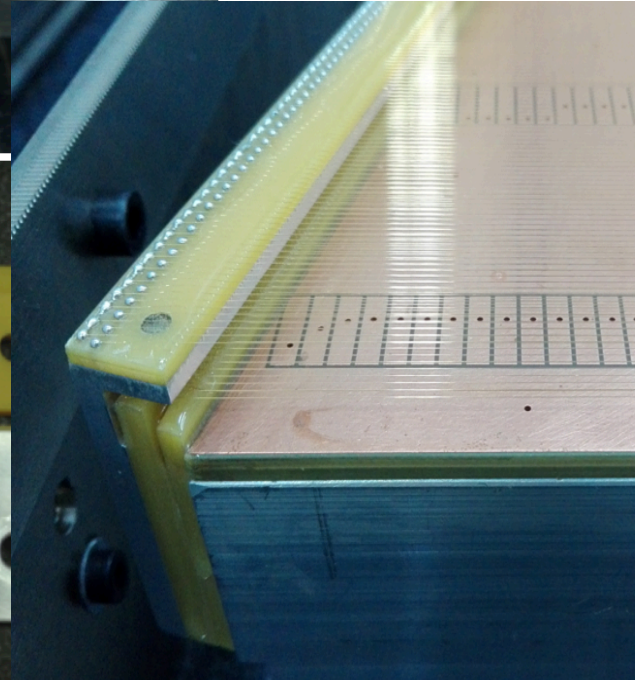
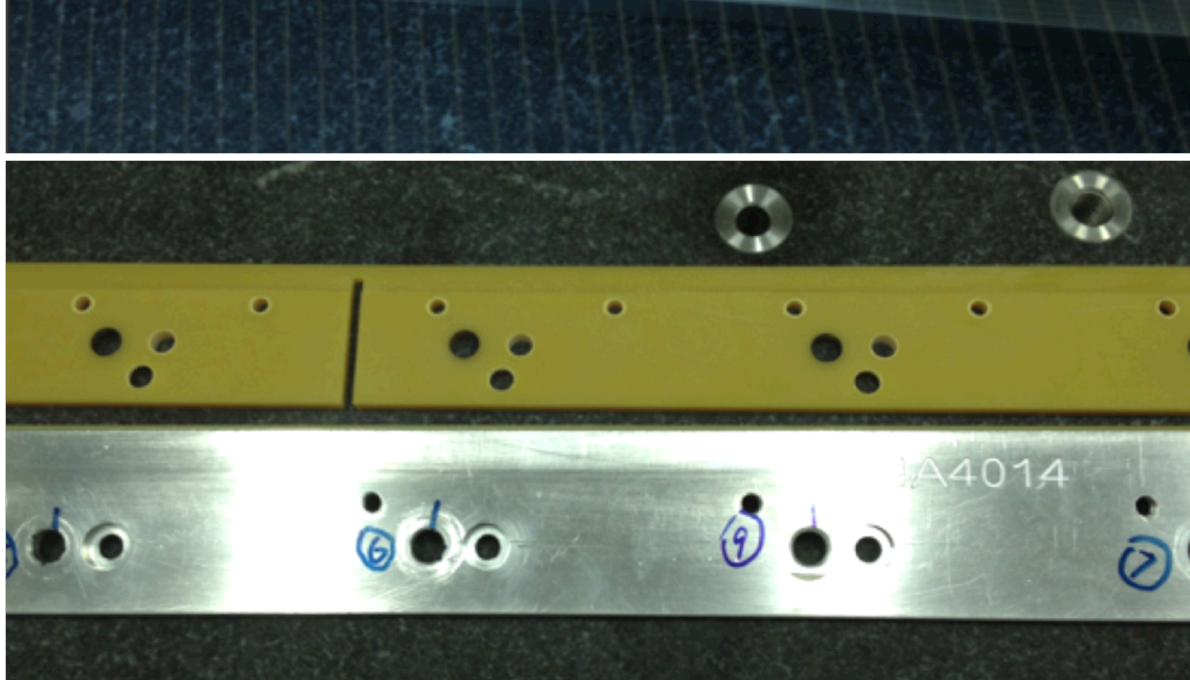
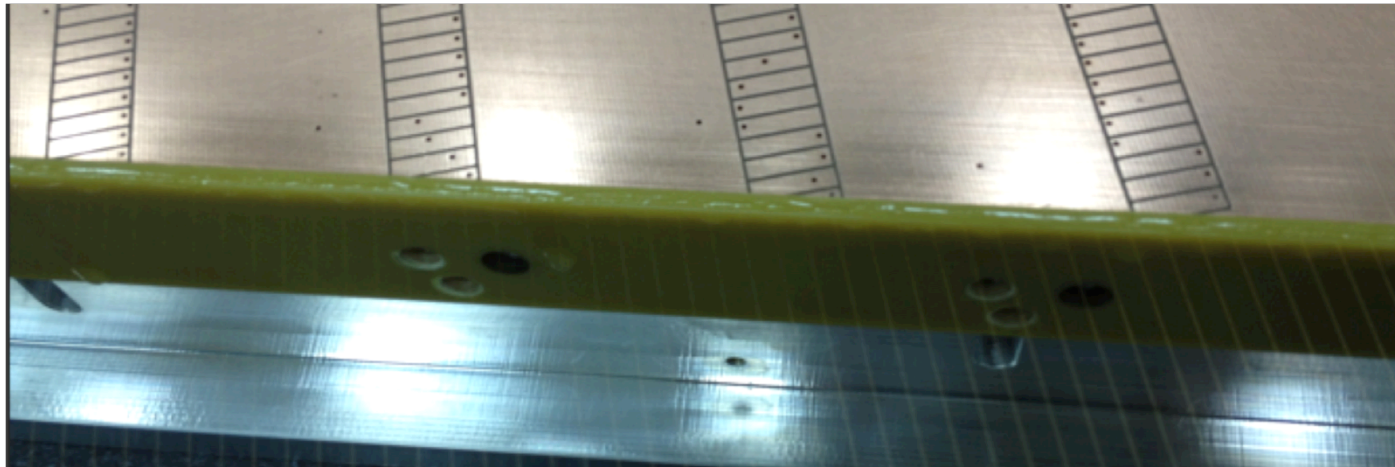


- Wire pitch and height is controlled by wire comb as originally used in STAR TPC.
- The flatness of straight edge should be $<10\mu\text{m}$.
- The combs produced by LBL/BNL will be used.

- Mounting wire combs using height standard (tolerance $<10\mu\text{m}$) and micrometer ($1\mu\text{m}$).
- Lowering down the frame to let the wire just touch the comb straightedge using micrometer head.

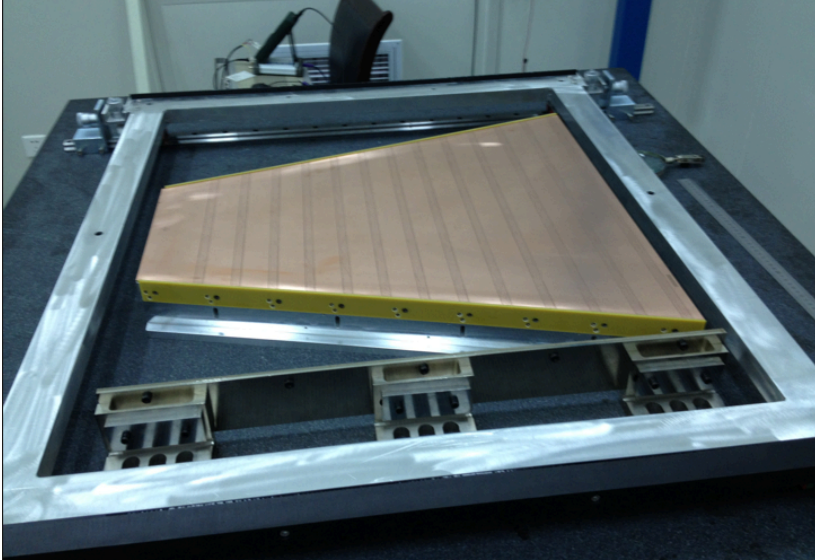


Side wire mounts to hold the wire plane



-Anode wire mounts glued, Shield & gated wire mounts installed with pin and screws

Mounting the anode wires



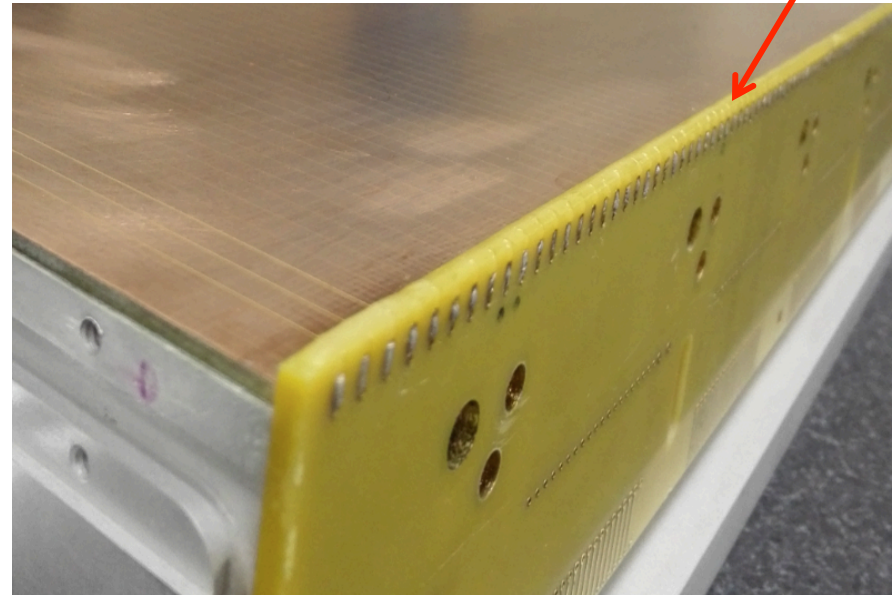
164 20um W wire
6 "fat" wire to lower the gain
on the edge

Original recipe on epoxy:
Epon 826 /Versamid 140 (3/2)
40 h to cure

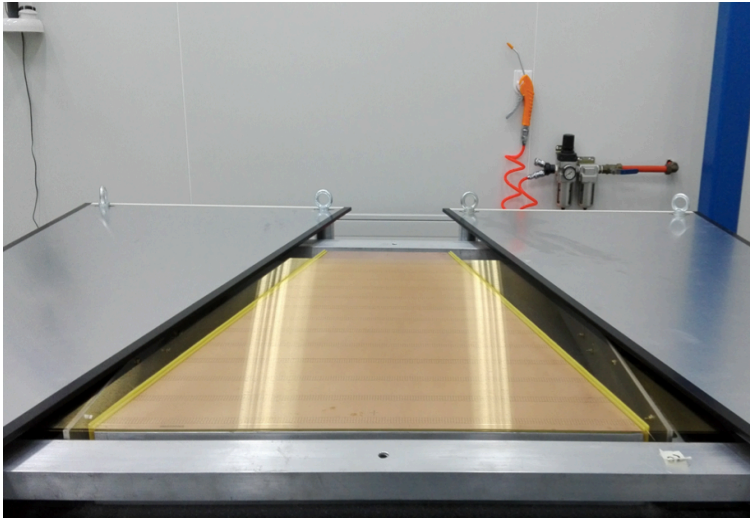
Modern recipe:
Araldite 2011-/AB (5/4)
24h to cure

Epoxy glued

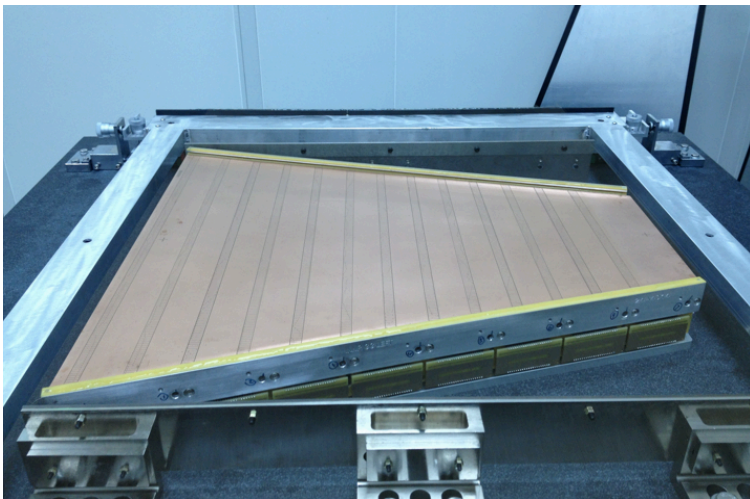
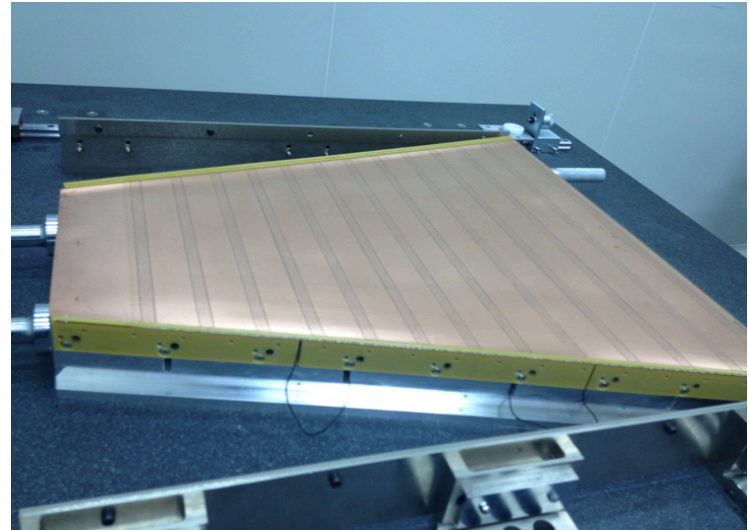
-Amine blush -> dry N² for curing?



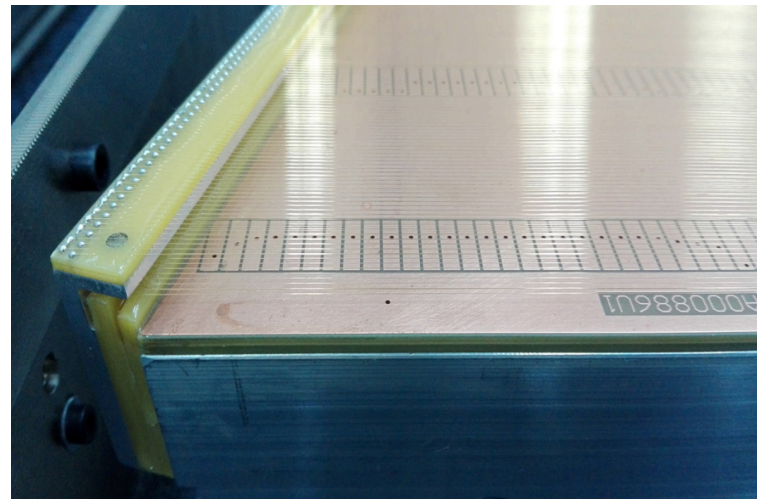
Mounting the shield & gated wires



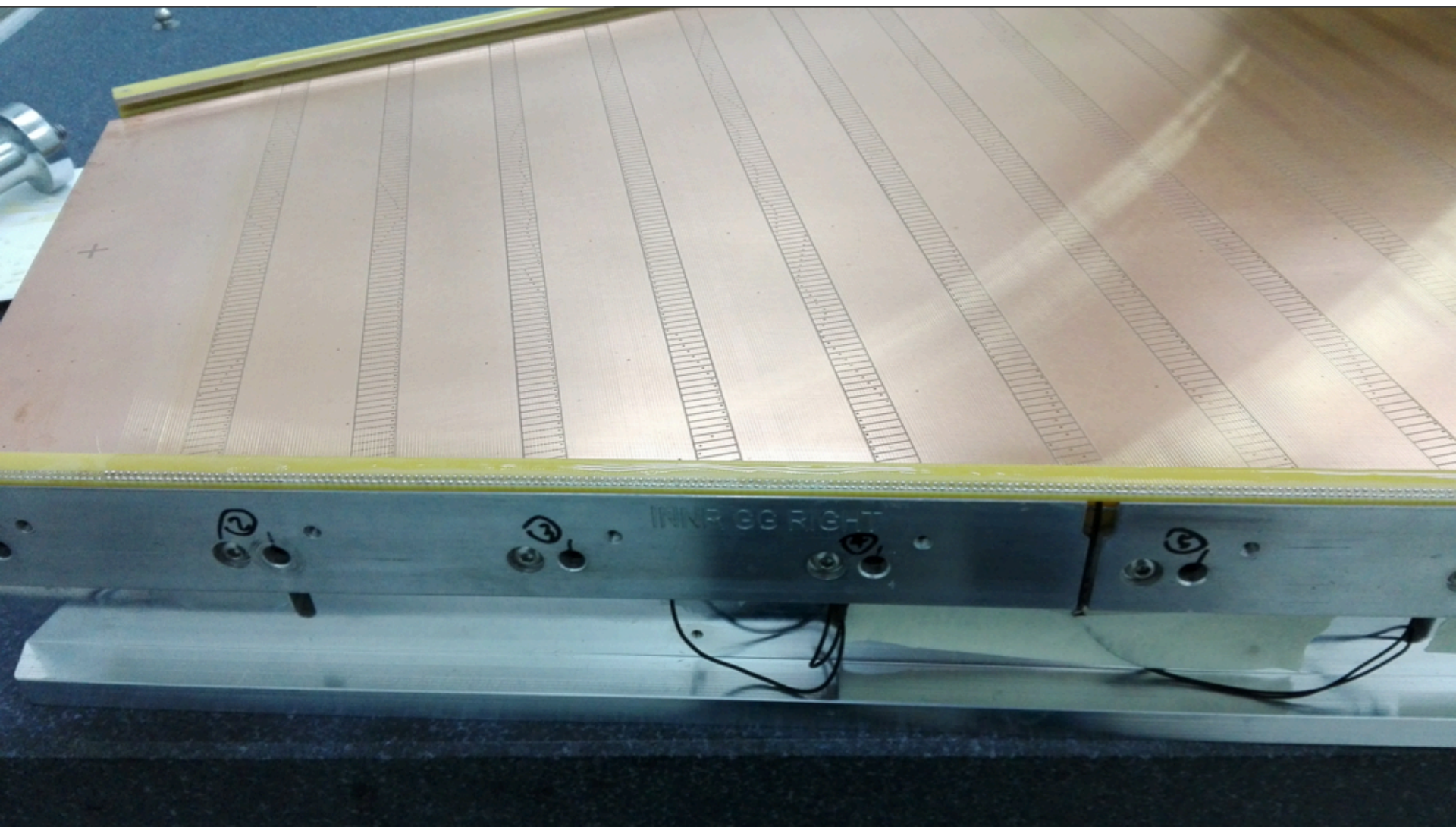
Shield wire plane epoxied and soldered



Gated wire plane epoxied and soldered

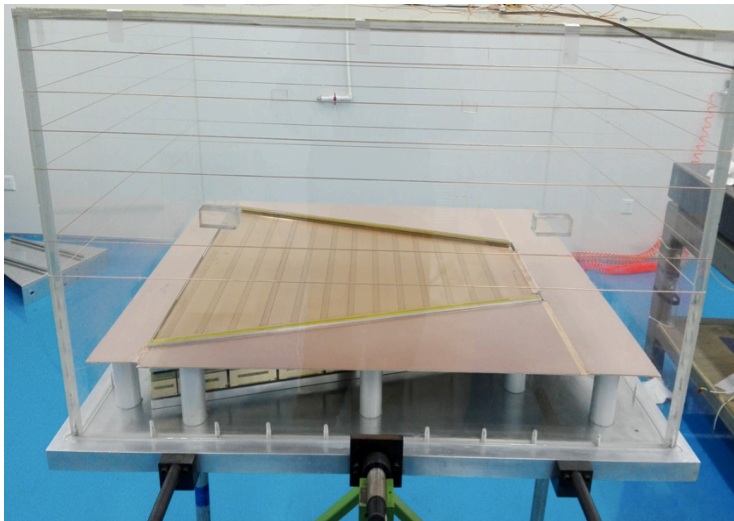
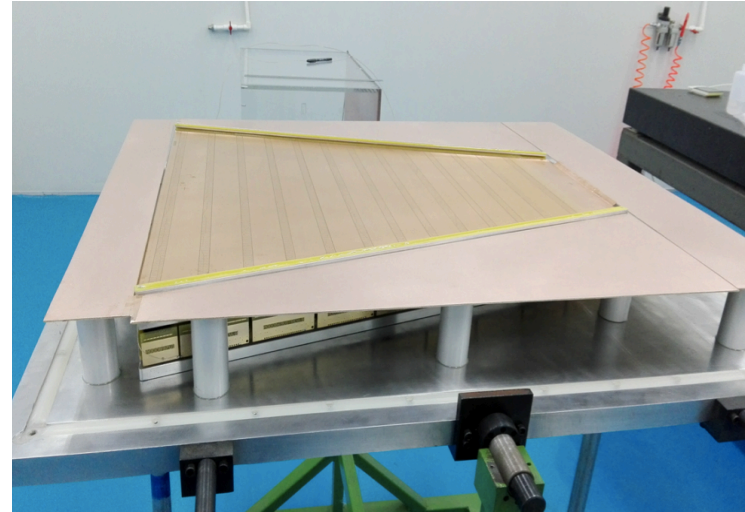
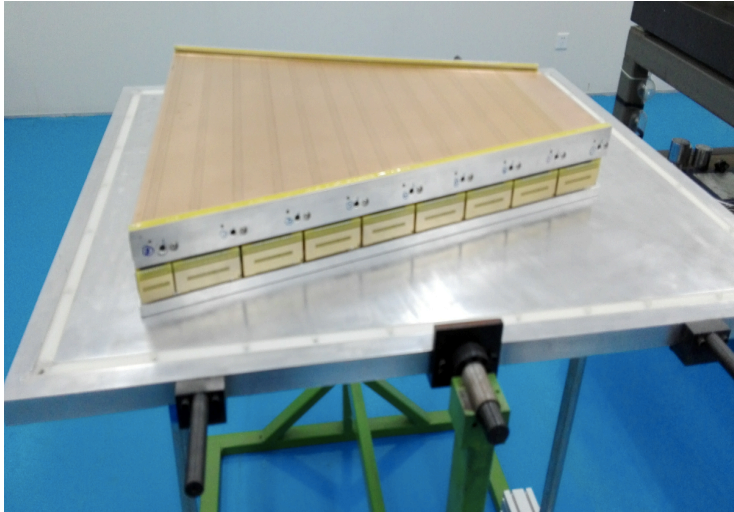


Gated wire soldered (681 solder points)



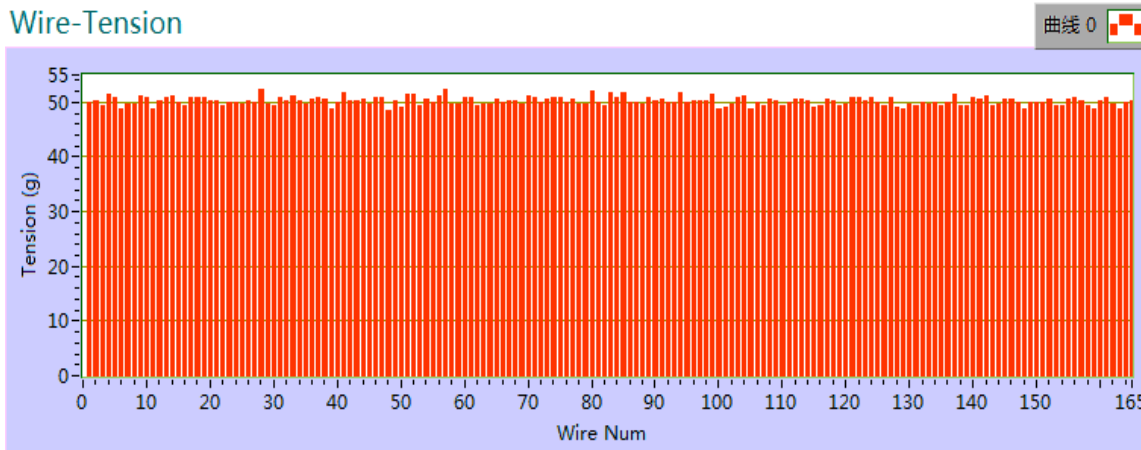
Sector in a Chamber

- 1st pre-prototype finished Jan. 2016, put it in a test chamber with STAR DAQ system

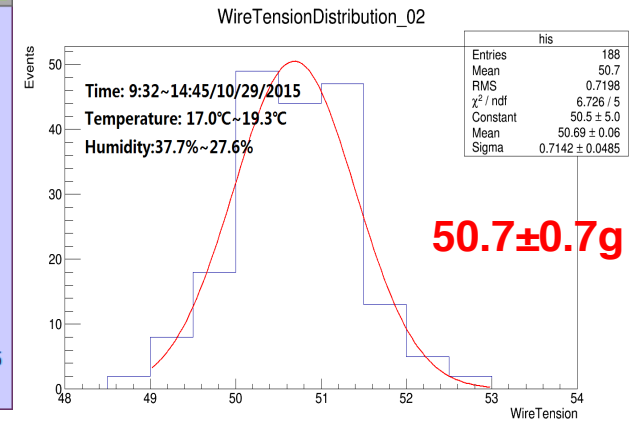


Wire tension measurement –Test frame #1 (20um)

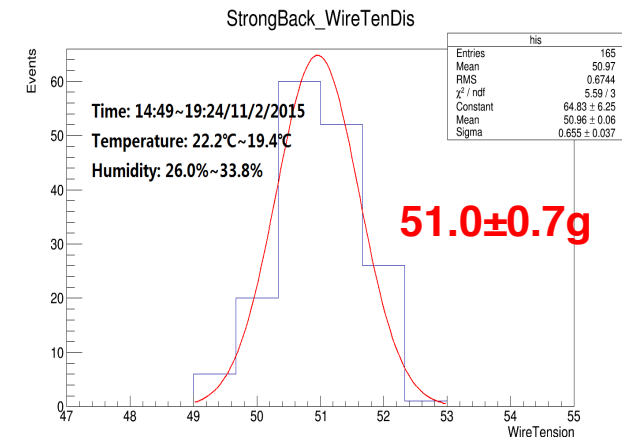
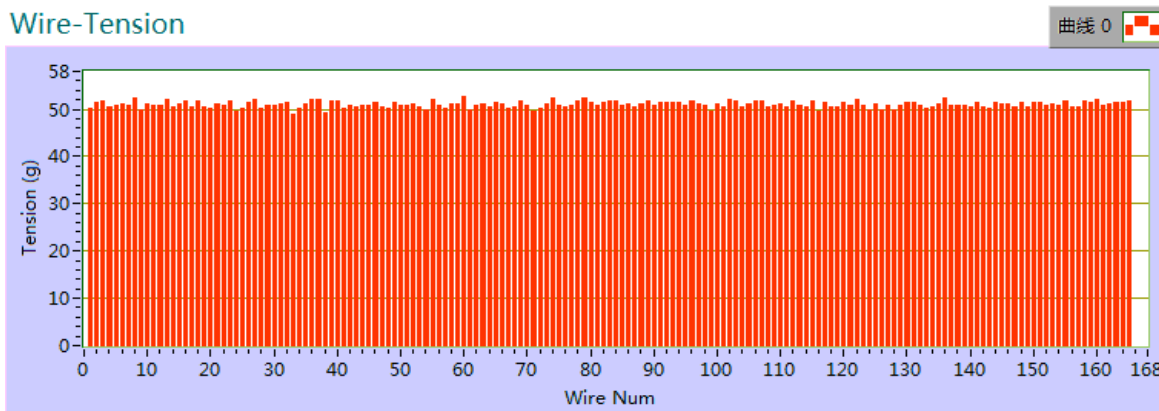
- Measured tension of 165 wires on wire frame:



Required to be $0.5 \pm 0.05N$
($51 \pm 5\text{gram}$)

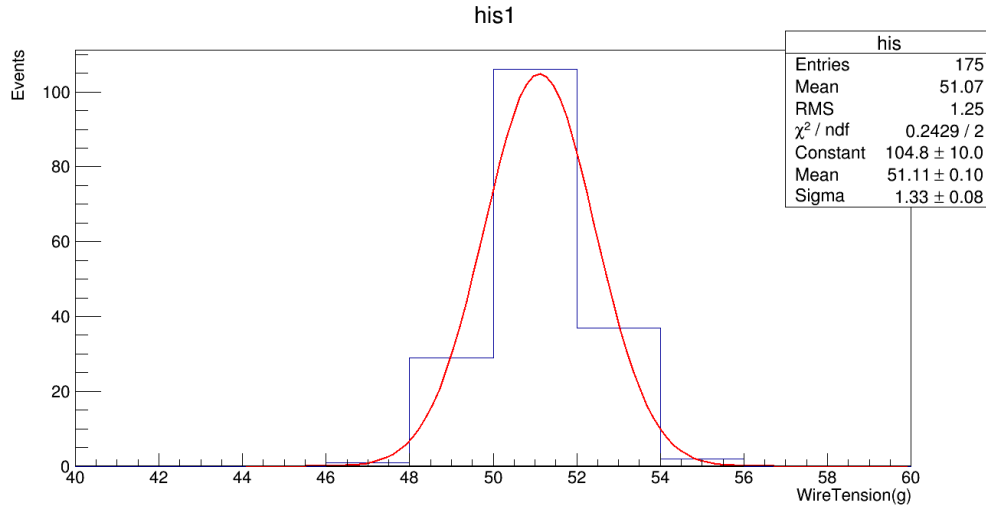


- Measured tension of 165 wires after glued on anode wire mounts:



Wire tension measurement –Test frame #2 (20um)

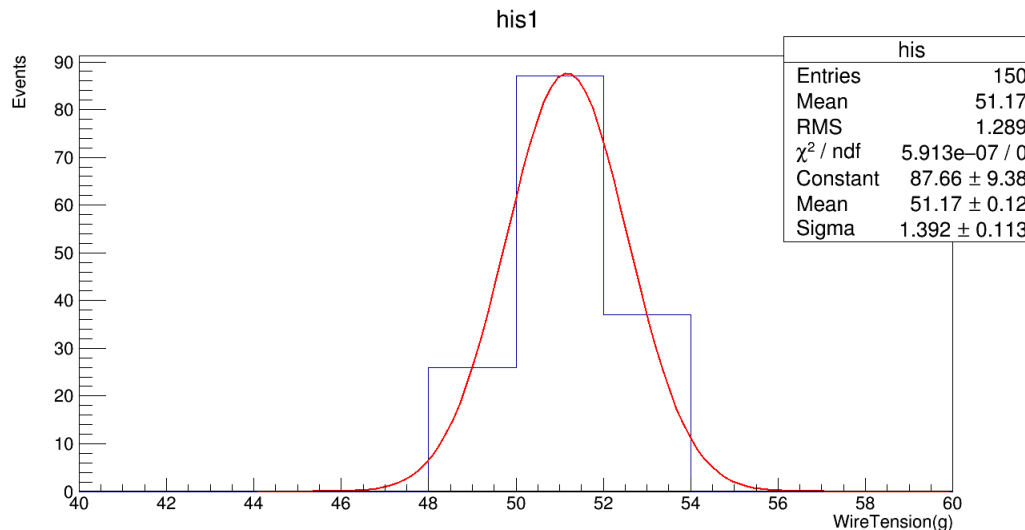
- Measured tension of 175 wires on wire frame:



Required to be $0.5 \pm 0.05\text{N}$
($51 \pm 5\text{gram}$)

$51.1 \pm 1.3\text{g}$

- Measured tension of 165 wires after being glued on anode wire mounts:

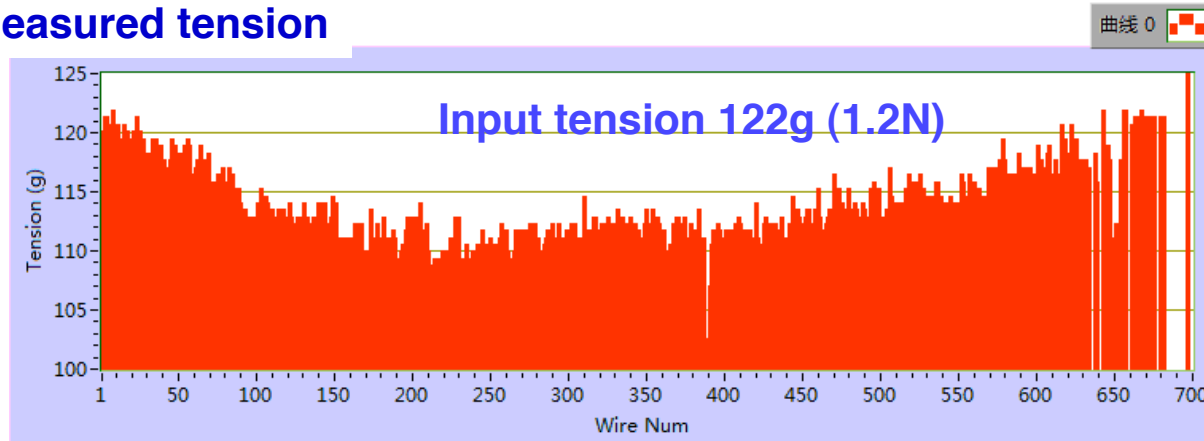


$51.2 \pm 1.3\text{g}$

Wire tension distribution for 1.2N BeCu Wire frame

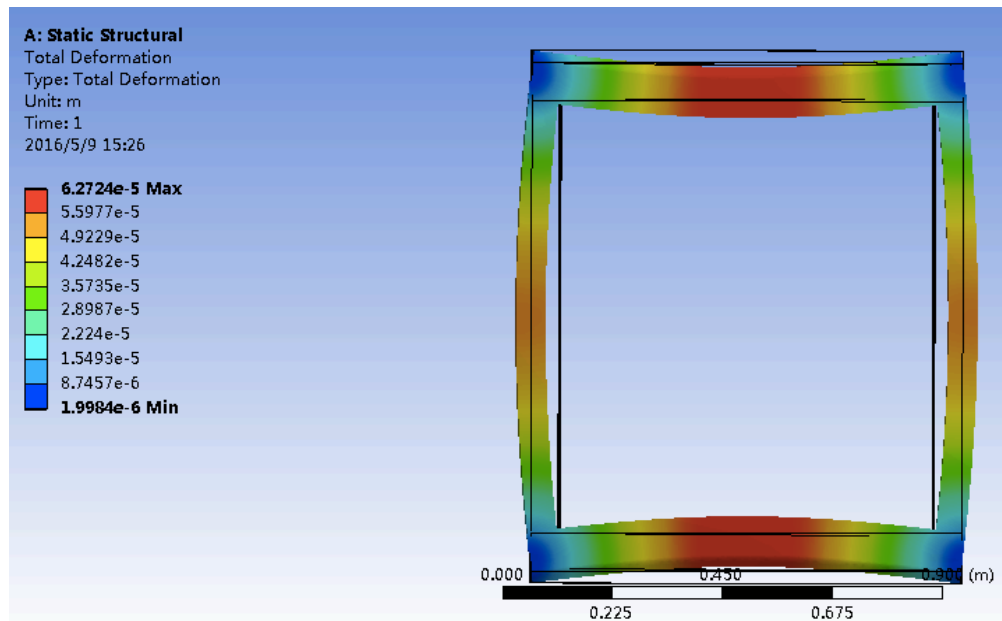
- Tension drop due to deformation of wire frame (similar as original one):

Measured tension



Total load ~80Kg

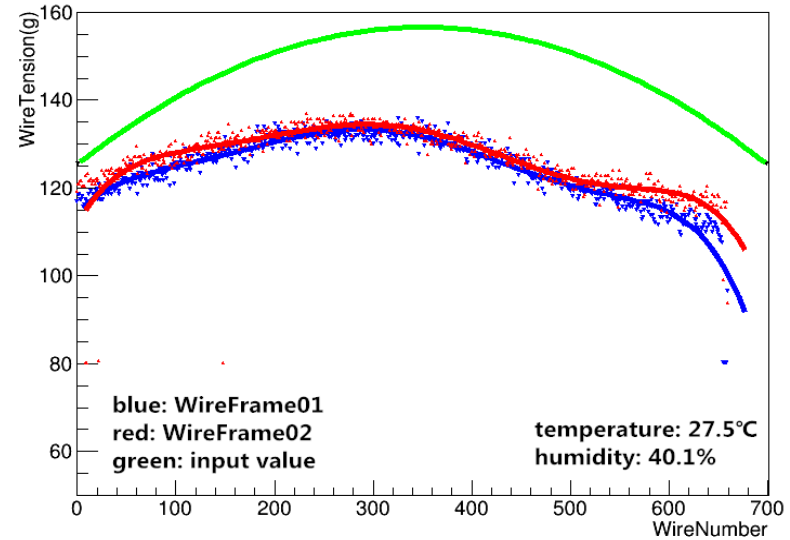
- ANSYS simulation



Consistent with
distortion
measurement
~60um

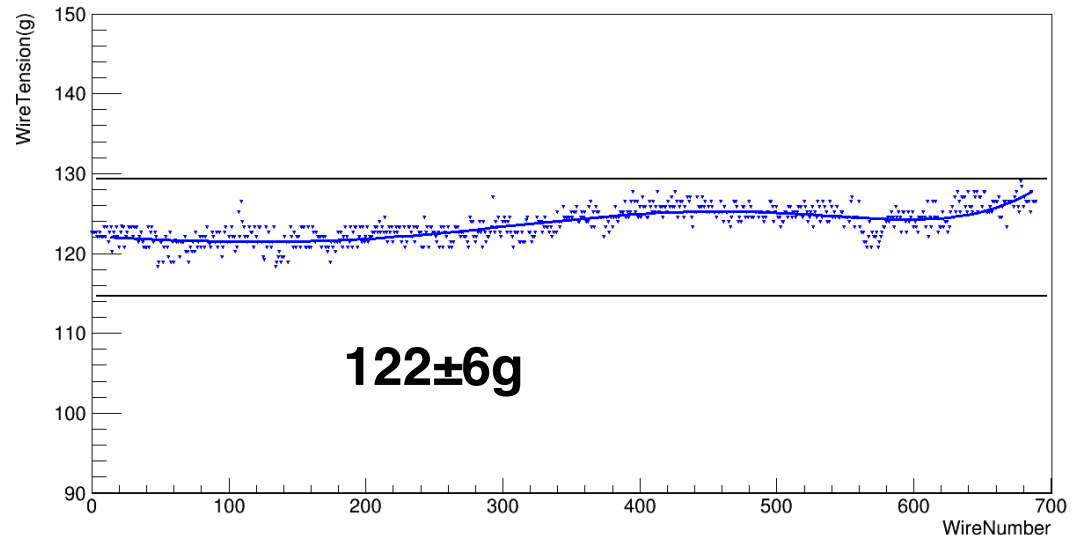
Wire tension distribution for 1.2N BeCu Wire frame

- Programming on the tension for each wire while wire winding after including the distortion effect for BeCu wire plane -an example



First Measurement

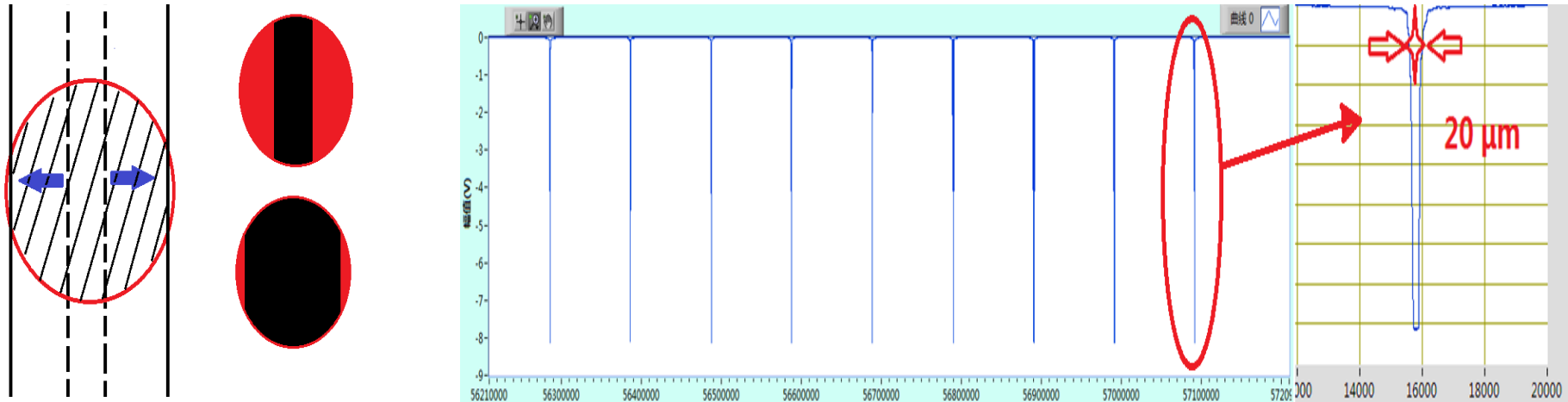
- Obtained the desired tension by tuning the input curve on tension:



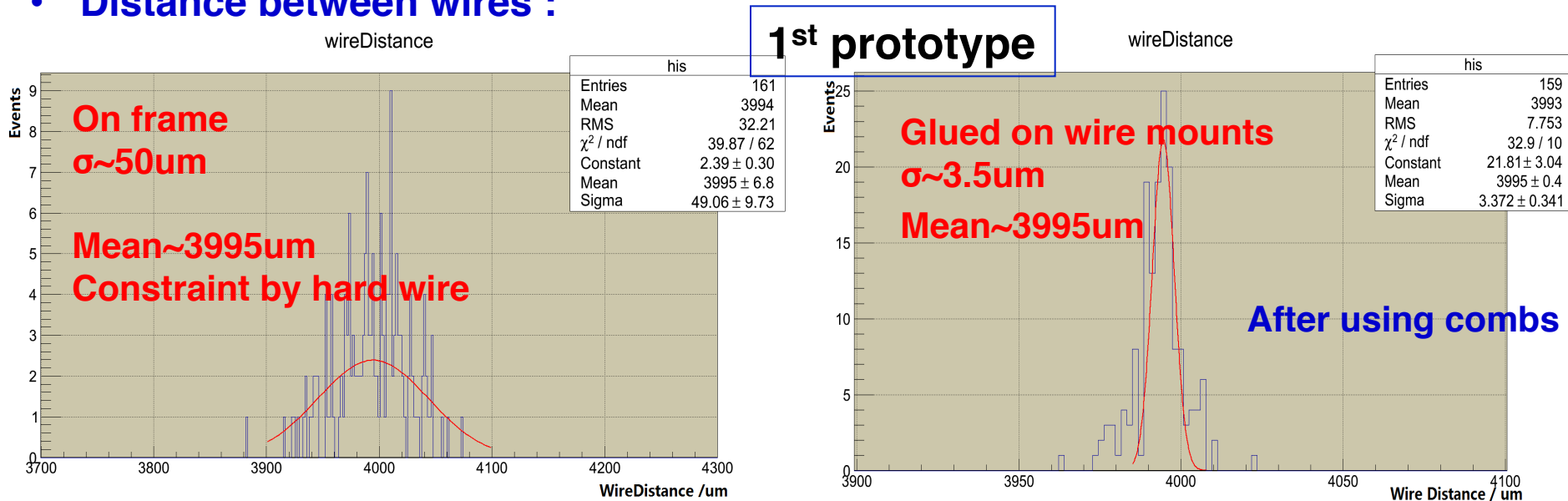
- $122 \pm 6g$ is consistent with traveller and STAR TPC in 1990's

Measure the pitch of wires using the same laser system

- Focusing the laser on each wire, width of response is the wire diameter

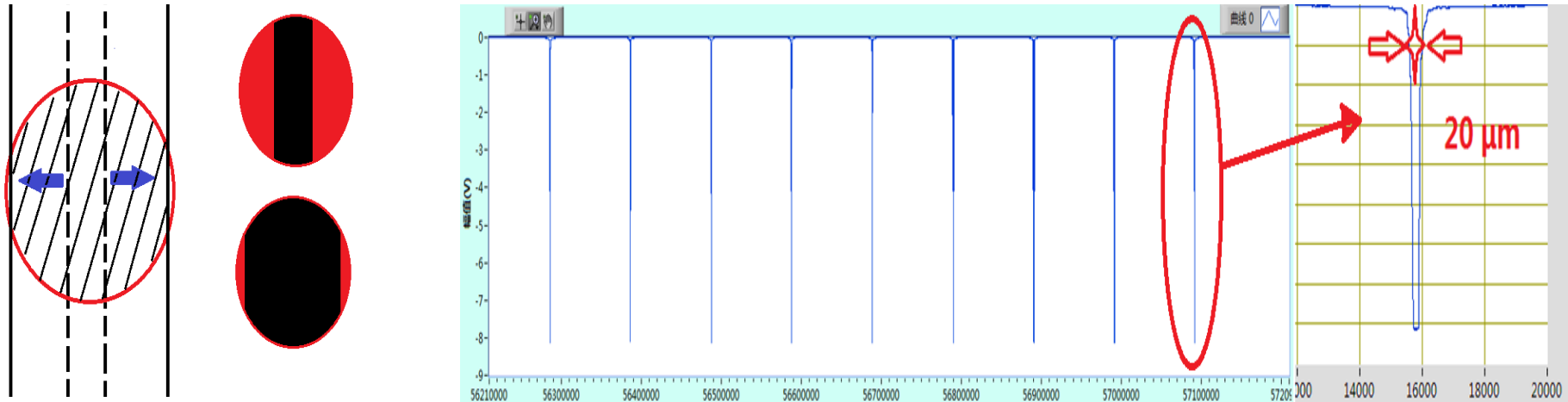


- Distance between wires :

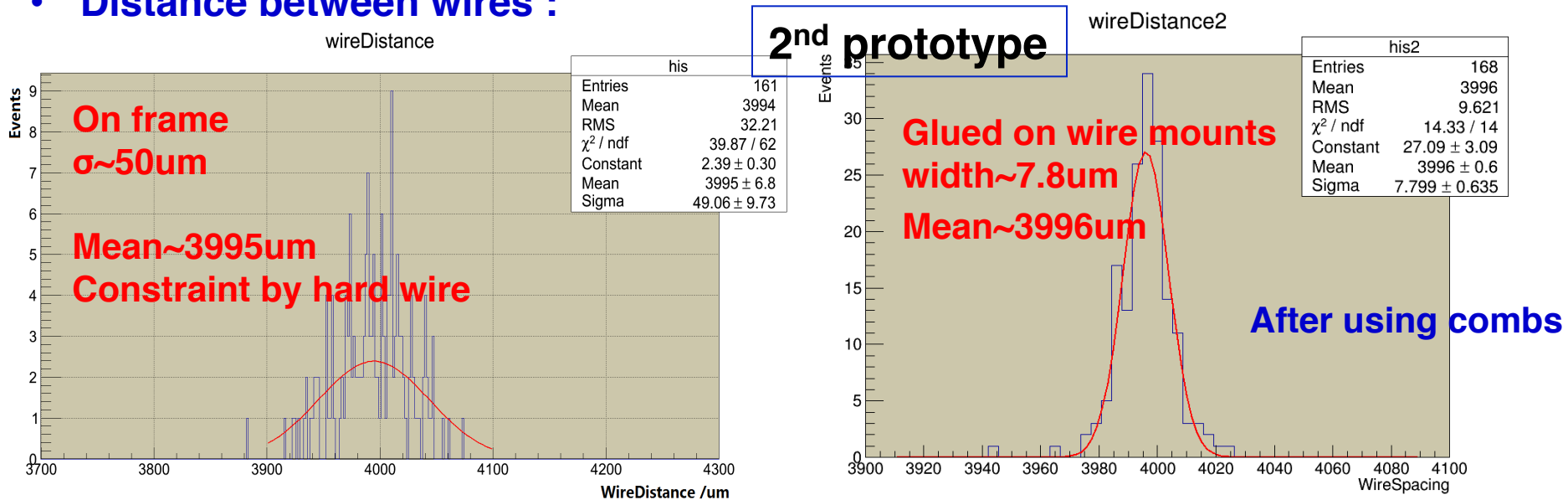


Measure the pitch of wires using the same laser system

- Focusing the laser on each wire, width of response is the wire diameter

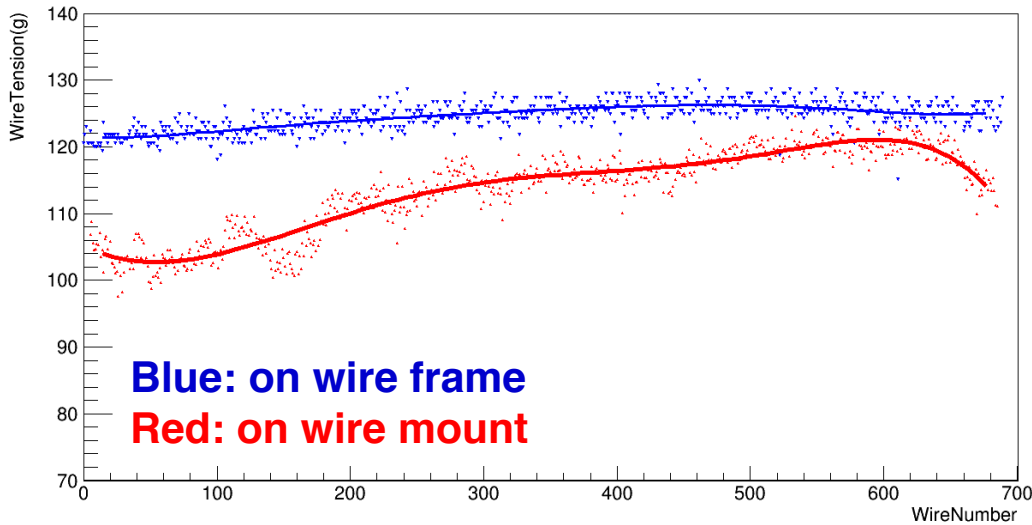


- Distance between wires :



Shield wire tension before & after mounted on sector

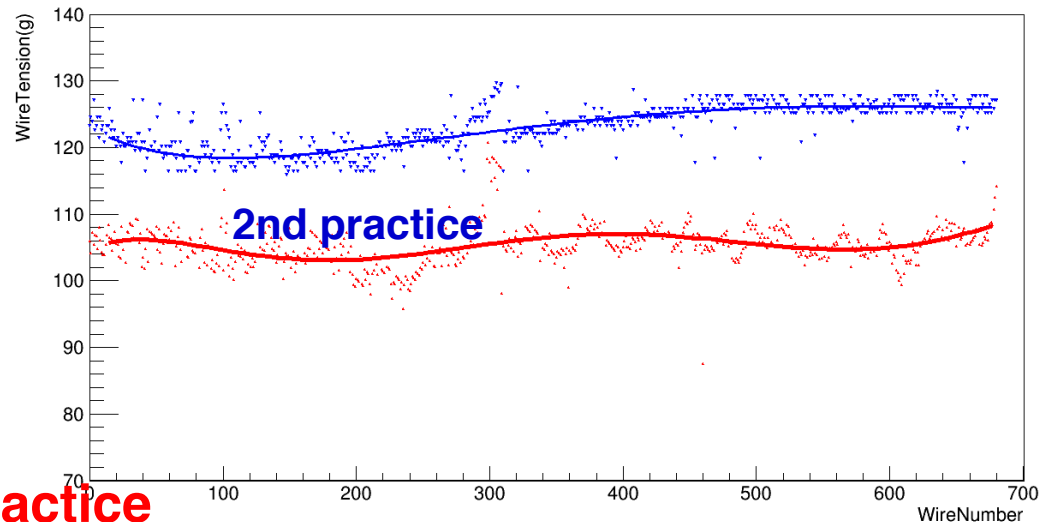
Comparison of experimental data



1st practice

Blue: on wire frame
Red: on wire mount

Comparison of experimental data



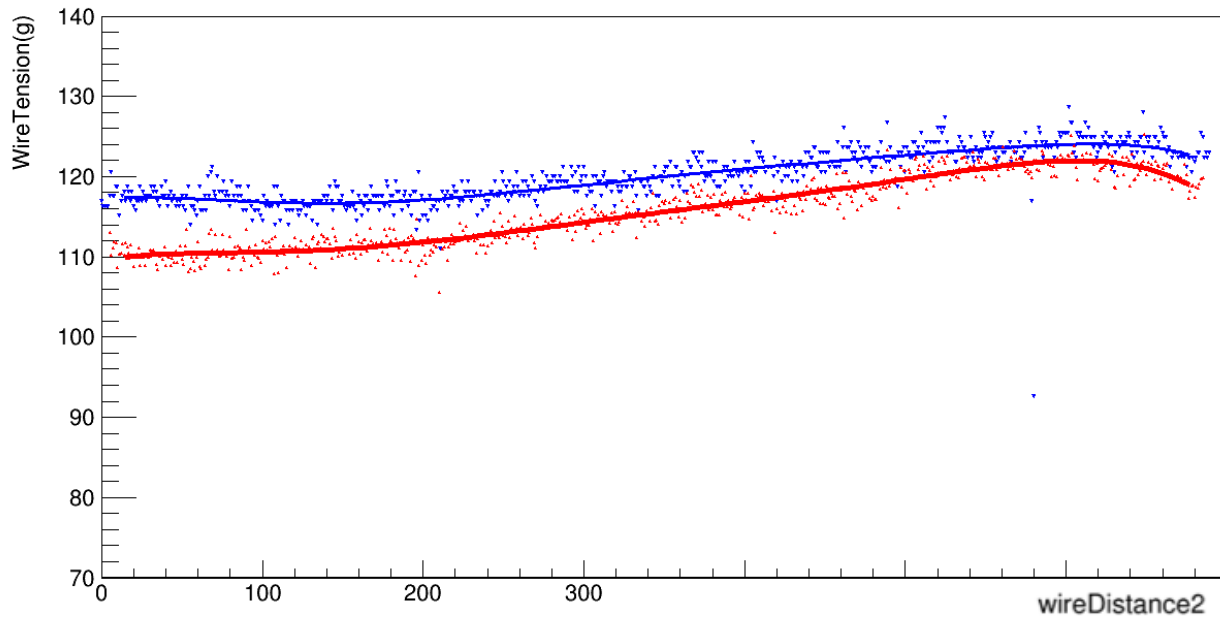
2nd practice

**10~20g tension reduction,
need further investigation**

**-Further investigation/practice
with final materials**

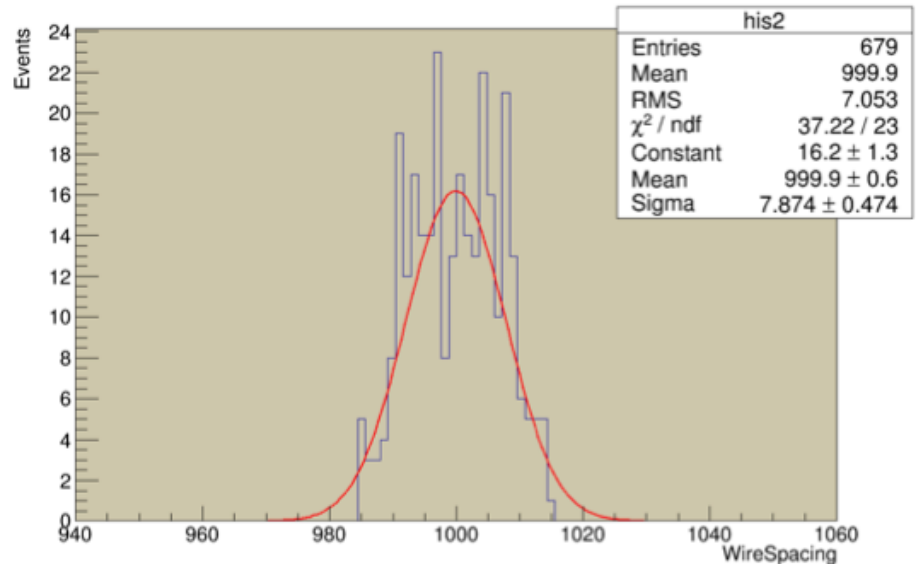
Gated wire tension before & after mounted on sector

Comparison of experimental data

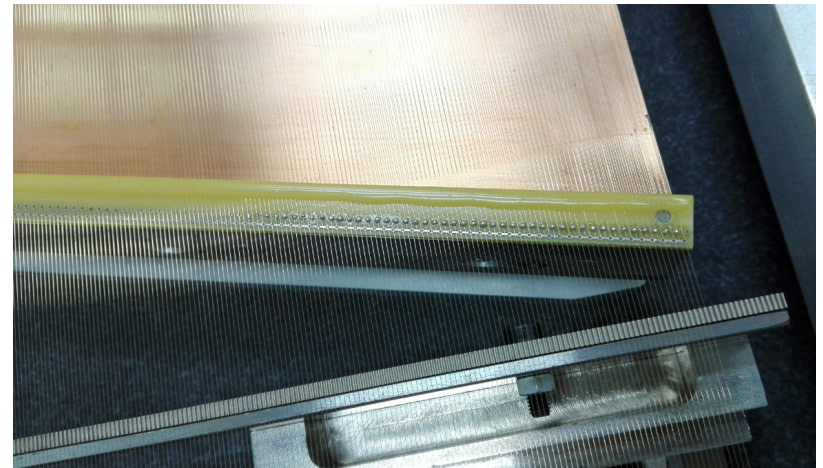
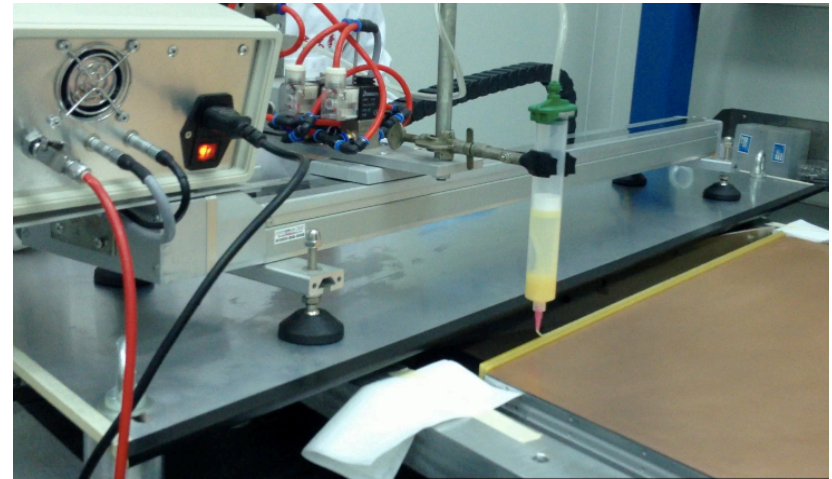


- Need to further monitor the tension after mounted in further prototyping with final strongback & wire mounts
- The wire pitch remains good precision (10um)

-Further investigation/practice with final materials

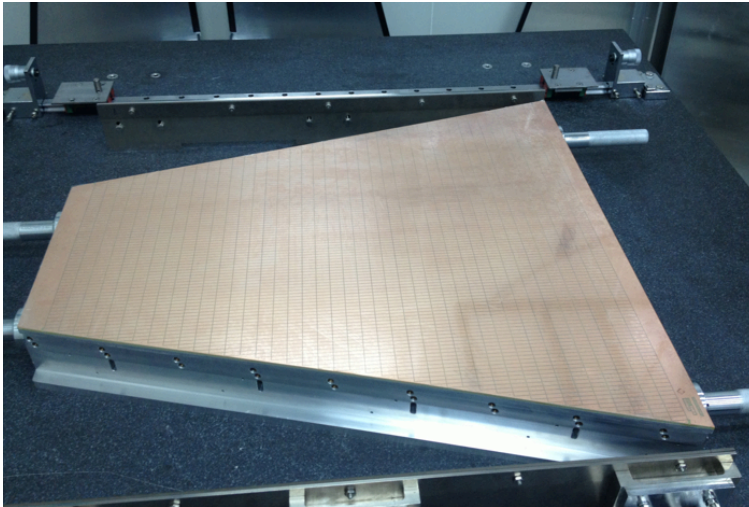


Practicing MWPC & assembly this summer

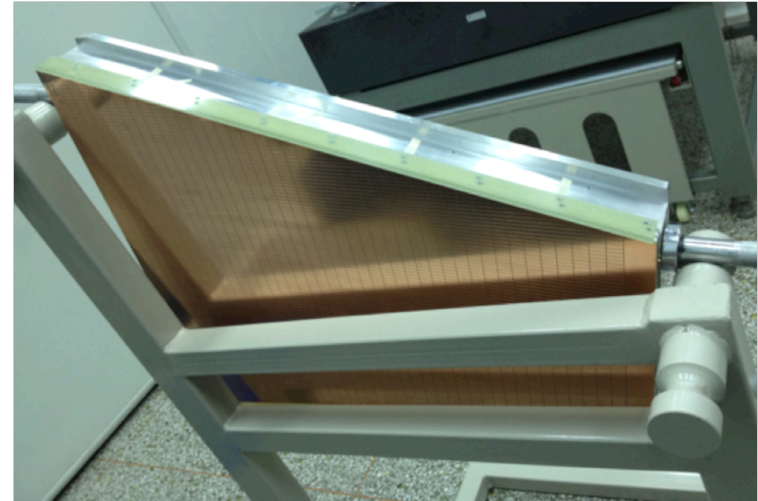


-Practiced twice the whole procedure of mounting 3 layers of wire using plane pcb, strongback, side wire mounts produced in China (not official)

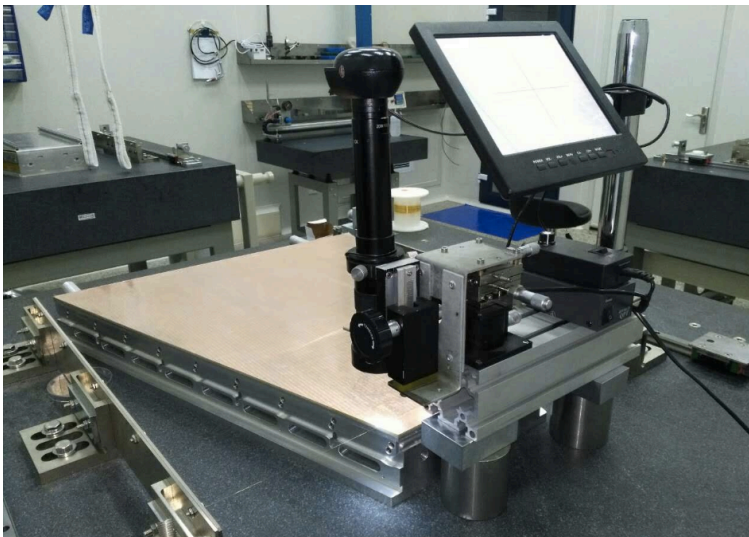
Prototyping with final design material ongoing



New pad plane glued

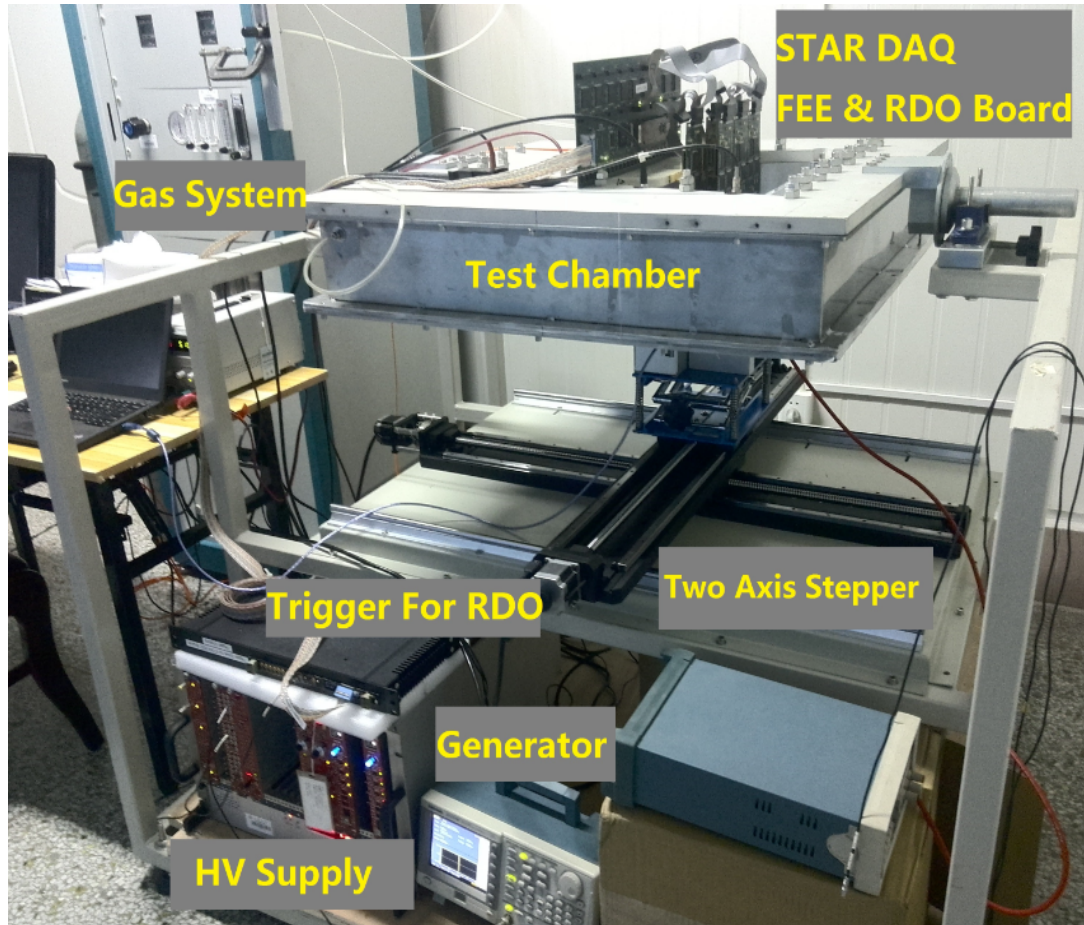


Epoxying anode wire mounts



**One set of strongback , pad plane & screws received in September.
Final side wire mounts to come.**

Testing system for mass production at SDU

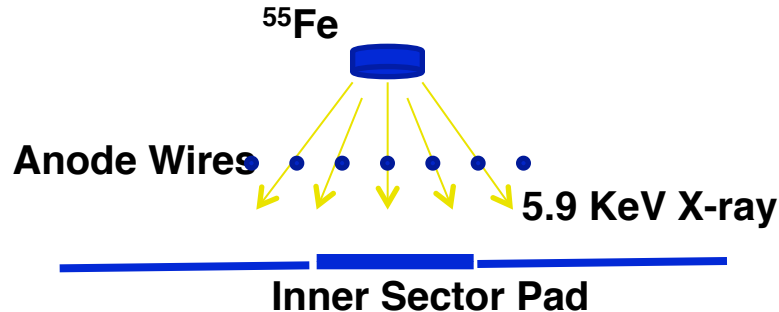


Test chamber: 5cm drifting length

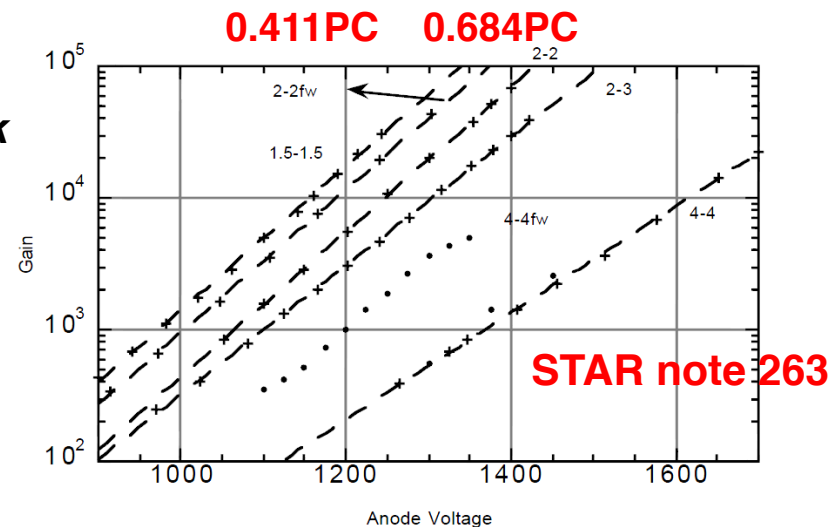
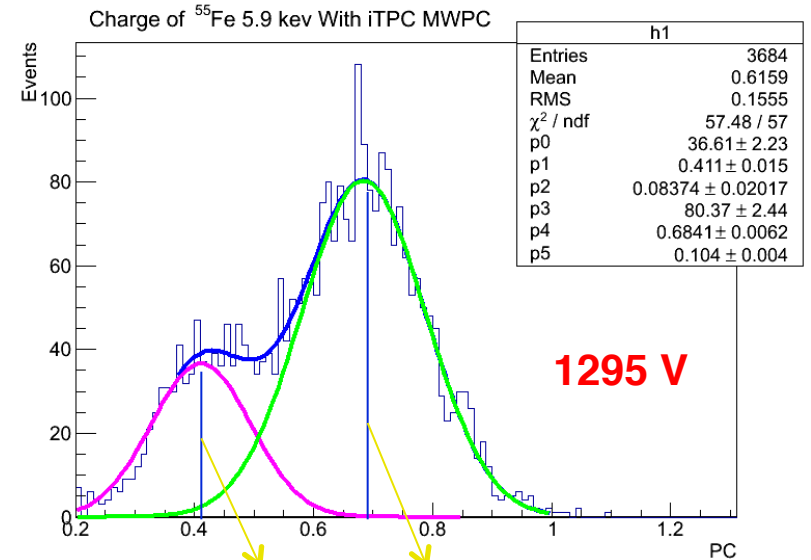
- 2D movable X-ray system for gain scanning
 - Fe55 and X-ray ready
 - DAQ system from BNL
- Testing plan for mass production:
 - Sector burn-in and leak current
 - Quantity to check with HV:
 - ✓ Efficiency (pad response)
 - ✓ Gain uniformity (wire scan using Fe⁵⁵ source)
 - QDC in purchase for wire gain expected to come early 2017

Gain estimation with anode wire readout -1st look

- Anode wire readout with oscilloscope using Labview



- ⁵⁵Fe 5.9 KeV charge**
- ✓ **Charge : 0.68PC (1295V)**
- ✓ **Gain = 0.68 * 6.24 * 10⁶/225 = 18977**
- ✓ **The ratio of main peak charge to escape peak charge is 1.66**
- Energy resolution 35%**
- STAR note 263 HV versus gas gain**
 $Gain = e^{b*(V-V_0)} = 18360$



Assembly QA plan at SDU-local travellers



iTPC 制作检查簿

iTPC Travellers Book (SDU)

Sector # 编号: _____

Date 制作时间: _____



| 步骤 | 项目/Item | 检查表 Traveller | 进度 Status |
|----|----------------------------------|------------------|--------------|
| 1 | 丝轴线检查/wire | Traveler 1 | |
| | | Traveler 2 | |
| | | Traveler 3 | |
| 2 | 绕丝/wire winding | | |
| 3 | 丝框张力检测/wire tension | Traveler 4 | |
| | | Traveler 5 | |
| | | Traveler 6 | |
| 4 | 丝框存储/wire frame storage | | |
| 5 | 阳极丝框用前检测/anode wire frame prior | Traveler 7 | |
| 6 | 阳极丝粘接/epoxying anode wire | | |
| 7 | 阳极丝焊接/anode wire soldering | | |
| 8 | 阳极丝面检查/anode wire plane | Traveler 8 | |
| 9 | 阳极丝连通性、短路、高压检测/A continuity | Traveler 9 | |
| 10 | 阴极丝挂载安装/shield wire mounts inst. | Traveler 10 | |
| 12 | 阴极丝框用前检查/shield wire frame | Traveler 11 | |
| 13 | 阴极丝粘接/shield epoxying | | |
| 14 | 阴极丝焊接/shield soldering | | |
| 15 | 阴极丝面检查 / shield wire plane check | Traveler 12 | |
| 16 | 阴极丝连通性检测/shield wire continuity | Traveler 13 | |
| 17 | 门极丝挂载安装/gated wire mounts inst. | Traveler 14 | |
| 18 | 门极丝框用前检查/gated wire frame | Traveler 15 | |
| 19 | 门极丝粘接/epoxying gated wire plane | | |
| 20 | 门极丝焊接/gated wire soldering | | |
| 21 | 门极丝短路、连通性检测/gated wire cont. | Traveler 16 | |
| 22 | <u>iTPC</u> 封装测试前检查 | Traveler 17 | |
| 23 | <u>iTPC</u> 测试 | Traveler 18 | |

Traveler example:

SD-TRAVELER S – 7 (LBL-S26)

ANODE WIRE FRAME PRIOR TO USE CHECK 阳极丝框使用前检验

RECORD ANODE WIRE WINDING NUMBER

记录阳极丝绕丝编号 #

RECORD WHICH ANODE WIRE FRAME USED

记录阳极丝框编号 #

After answering each of the following questions please initial your name.

完成下列检查后请签名。

VISUAL INSPECTION 外观检验

1. Is there kink in the wires?

丝有无扭曲?

Yes___, No___

2. Are any wires contaminated with oil, dirt, and/or lint?

丝有无任何油, 污垢或棉絮线头等污染?

Yes___, No___

3. Are there any discolorations of the wire?

丝有无任何变色褪色?

Yes___, No___

4. Are there any missing wires in the wire frame?

丝面上有无任何缺失的丝?

Yes___, No___

5. Are there noticeable change in the wire tension? (Look for sags or noticeable catenary effect)

有无易见的丝张力变化? (寻找易见的丝下垂等变化)

Yes___, No___

6. Are there any broken wires?

有无任何断线?

Yes___, No___

IF INSPECTION HAS FAILED, BAG AND TAG "REJECTED WIRE FRAME" AND MARK BELOW AND PUT THEM IN "REJECT STORAGE AREA".

如果外观检验未通过, 收起丝面并标注“驳回-丝框”并在下面标注, 把它们放入“驳回储存区”

Engineer's signature

工程师签名_____

Inspection date

检验日期: ___/___/201_

Inspector's signature

检验员签名_____

Inspection date

检验日期: ___/___/201_

PASS通过_____

REJECTED驳回_____

Production procedure – strictly being followed



iTPC Production Procedure

iTPC 丝室制作流程

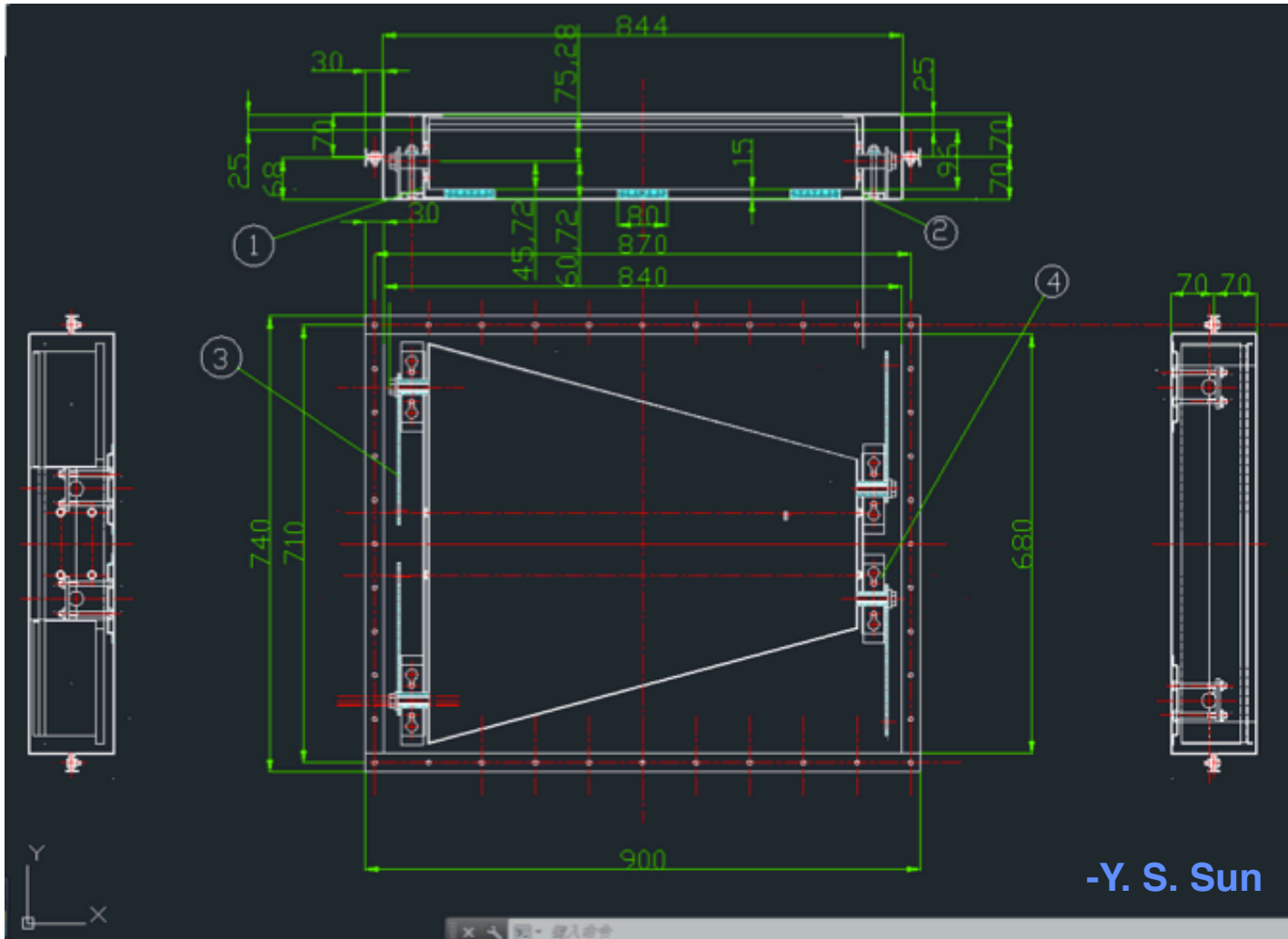


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Shipping box design underway



Just made the 1st prototype of the storage box (part of the shipping box)

Time cost per sector for mass production

- **2~3 weeks for detector assembly, 1 week for test**

| | items | Time cost (day) |
|------------|----------------------|-----------------|
| Inspection | Inspection & check | 1 |
| Assembly | Anode wire mounting | 4 |
| | Shield wire mounting | 3 |
| | Gated wire mounting | 4 |
| Testing | HV burn-in | 1 |
| | Efficiency | 2 |
| | Gain & uniformity | 2 |

- **One day for inspection & checks for pad plane and side wire mounts**
- **Above estimate based on modern epoxy Araldite 2011/AB (24h) -> 12 days in total**
- **Original epoxy (Epon 826+Versamid 140, 40h) will add 3 days ->15 days in total**

Production plan & schedule

Sector arrival from LBL

| 3.6.6 | Production | 408 days | Tue 3/21/17 | Thu 10/25/18 # |
|----------|------------------------|----------|--------------|----------------|
| 3.6.6.1 | Assemble with MWPC | 90 days | Tue 3/21/17 | Mon 7/24/17 # |
| 3.6.6.2 | Test | 84 days | Mon 4/10/17 | Thu 8/3/17 # |
| 3.6.6.3 | Ship to BNL | 20 days | Fri 8/4/17 | Thu 8/31/17 # |
| 3.6.6.4 | First 6 modules at BNL | 0 days | Thu 8/31/17 | Thu 8/31/17 # |
| 3.6.6.5 | Assemble with MWPC | 90 days | Tue 7/25/17 | Mon 11/27/17 # |
| 3.6.6.6 | Test | 84 days | Mon 8/14/17 | Thu 12/7/17 # |
| 3.6.6.7 | Ship to BNL | 20 days | Fri 12/8/17 | Thu 1/18/18 # |
| 3.6.6.8 | Nextt 7 modules at BNL | 0 days | Thu 1/18/18 | Thu 1/18/18 # |
| 3.6.6.9 | Assemble with MWPC | 90 days | Tue 11/28/17 | Mon 4/16/18 # |
| 3.6.6.10 | Test | 84 days | Mon 12/18/17 | Thu 4/26/18 # |
| 3.6.6.11 | Ship to BNL | 20 days | Fri 4/27/18 | Thu 5/24/18 # |
| 3.6.6.12 | Next 6 modules at BNL | 0 days | Thu 5/24/18 | Thu 5/24/18 # |
| 3.6.6.13 | Assemble with MWPC | 90 days | Tue 4/17/18 | Mon 8/20/18 # |
| 3.6.6.14 | Test | 84 days | Mon 5/7/18 | Thu 8/30/18 # |
| 3.6.6.15 | Ship to BNL | 20 days | Fri 8/31/18 | Thu 9/27/18 # |
| 3.6.6.16 | Last 7 modules at BNL | 0 days | Thu 9/27/18 | Thu 9/27/18 # |

Last 7 ship to BNL

STAR TPC MWPC production internal review report

Review in August, 2016

The STAR-iTPC MWPC production internal review was held in Shandong University, Jinan on August 3rd 2016. Review committee members include: Jin Li (IHEP,CAS), Zi-zong Xu(USTC), Yi Wang(Tsinghua U.), Jian-song Wang(IMP, CAS), Li-min Duan(IMP,CAS).

The committee also provided some detail comments and suggestions, which include:

1. Checking the shield wire tension before and after wire mounting. If the tension changed, provide specific solution. -to be done
2. Considering the pressure change in shipping period, and one possible method is linking the shipping box to a plastic bag. -to be done
3. Considering to do some shaking test to confirm the shipping safety. -to be done
4. Use quick dry epoxy on wire frame to speed up the production. -OK
5. Prepare detail fix method for broken wire, epoxy dropping on wire or pad plane, need to make some pre-arranged planning and do some exercise. -Done
6. Make good communication with US side, make sure all requested assembly material arrive on time without delay. Avoid waiting too long at the beginning and work in hurry in the end. -OK
7. After assembly cleaning, use nitrogen instead of clean air to clean the sector. -Done
8. Use fingerstall or glove when working on wire. -Done
9. Wire winding should be done in a relative clean room. -Done
10. Specific storage room. Suggest storing the strongback “standing up” to avoid the impaction from un-flat ground. -OK

-August review comments continued

11. Soldering must use 100% pure alcohol for cleaning. -to be done
12. After anode wire mounting, power the HV, test leak current and possible spark. -OK
13. Hire professional soldering engineer. Considering contact local State Commission of Science and Technology for National Defense Industry (COSTIND) to ask for help. - try both ways (training & hire)
14. May use flexible PCB for field cage. -OK
15. If STAR had spare TPC sector, move it to SDU and test it with new produced sector for comparison. -OK
16. Consider the tax free possibility and procedure for shipping. -OK
17. During working period, be careful with temperature and humidity. Especially in extreme weather condition, need to check more carefully or avoid working in such cases. -OK
18. Suggest to use new quick dry epoxy which ALICE TPC used to speed up the production, if new epoxy passes the Canary chamber test. -OK
19. The do's and don'ts and production precision request should be listed separately. -OK
20. When started the official production, the most important thing is the production itself. Don't need to care too much about working speed at the beginning. -OK

Risks and mitigation

- **Dust/fiber on wire plane, which may lead to spark for the sector**
 - > **build clean room for both wire winding and tension measurement**
 - > **Done**
- **Broken wire or sector damage during shipping from China to BNL**
 - > **build shipping box with safe design, make tests before shipping**
 - > **to be tested, one shipping box prototype made**
- **Broken wire during detector assembly**
 - > **replace the wire if possible, if not, then remove all the wire plane and redo the wire mounting**
 - > **practiced replacing one anode wire on wire frame**

Summary

- **Funding & manpower secured for prototyping and production of MWPC.**
- **Related tools & fixtures for production designed. QA procedure has been designed.**
- **The 1st pre-prototype finished. More practices and prototyping with final designed material underway.**
- **Set up of detector test system with Fe⁵⁵, X-ray. Detailed testing plan being finalized.**
- **1st internal review for MWPC on Aug. 3. Suggestions being taken.**
- **The mass production is scheduled to start March 2017.**

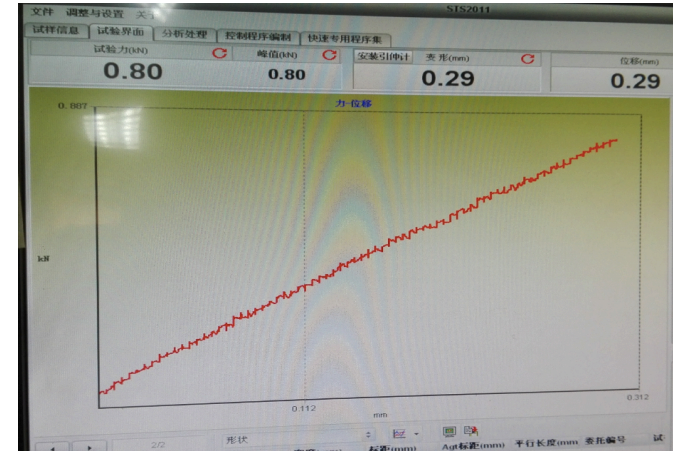
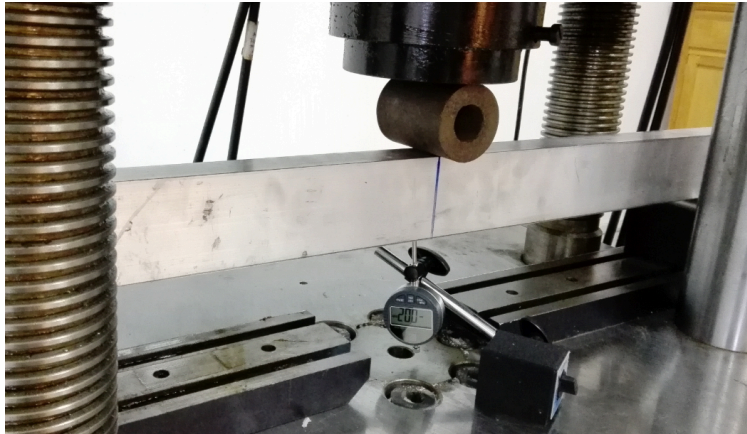
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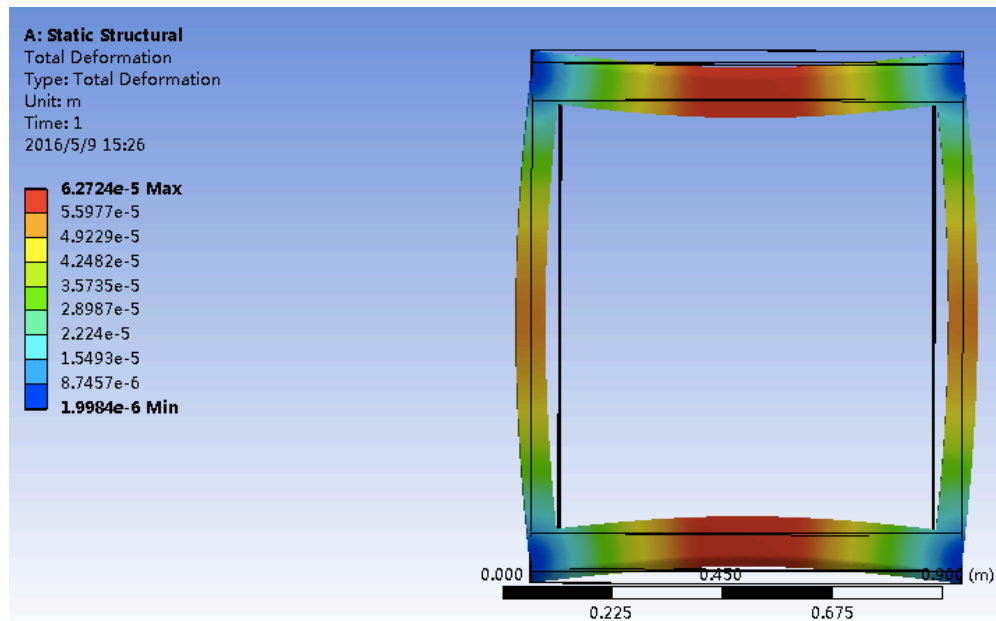
Thanks!

Wire tension distribution for 1.2N BeCu Wire frame

- Measurement of distortion:



- ANSYS simulation



Consistent with distortion measurement
~60um

